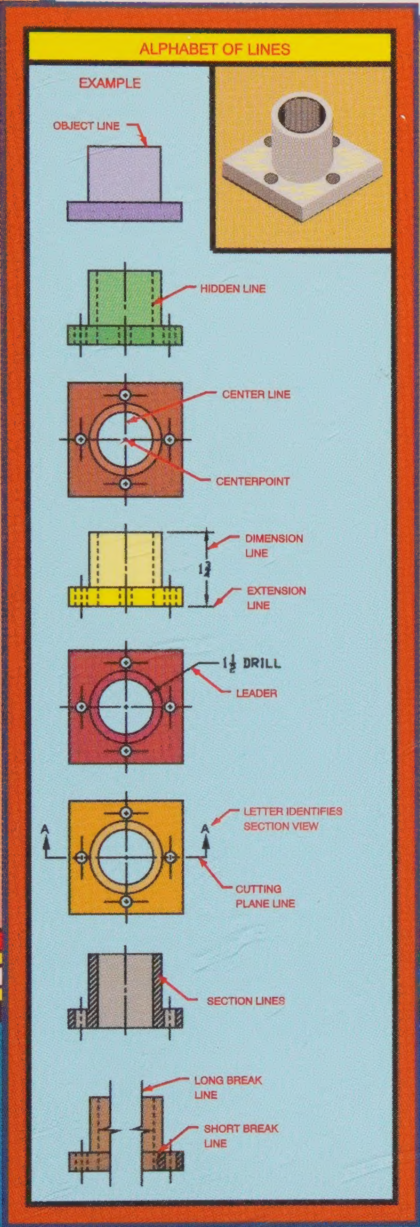
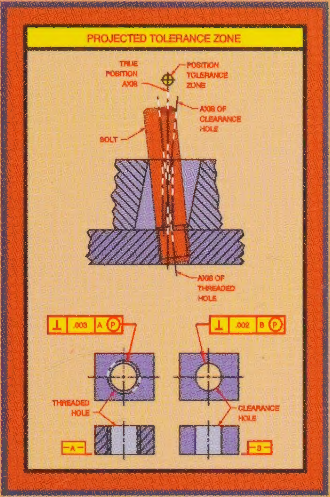
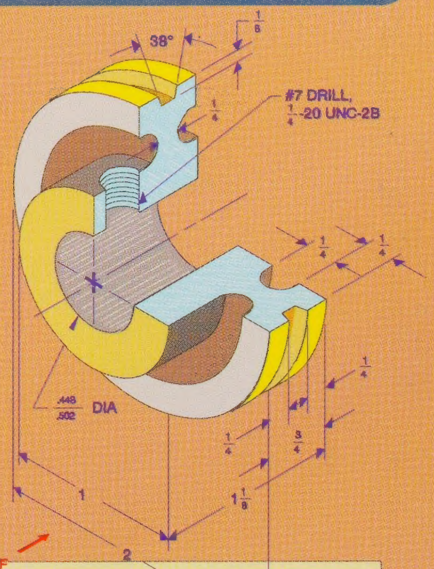
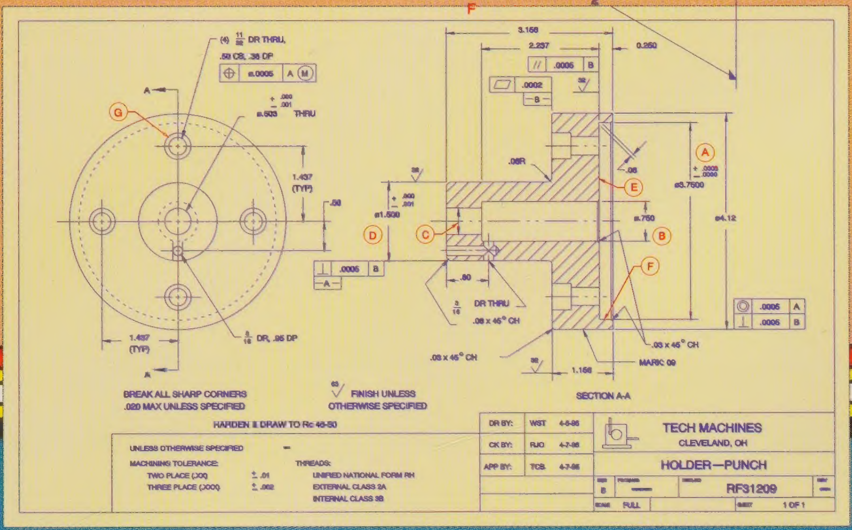
MACHINE TRADES PRINTREADING









Thomas E. Proctor
J. David Holloway
Jonathan F. Gosse

an atp publication

MACHINE TRADES PRINTREADING

AMERICAN TECHNICAL PUBLISHERS, INC.
HOMEWOOD, ILLINOIS 60430

Thomas E. Proctor
J. David Holloway
Jonathan F. Gosse

Acknowledgments

The authors and publisher are grateful to the following companies and organizations for providing technical information and assistance. Selected charts and prints have been modified for educational purposes.

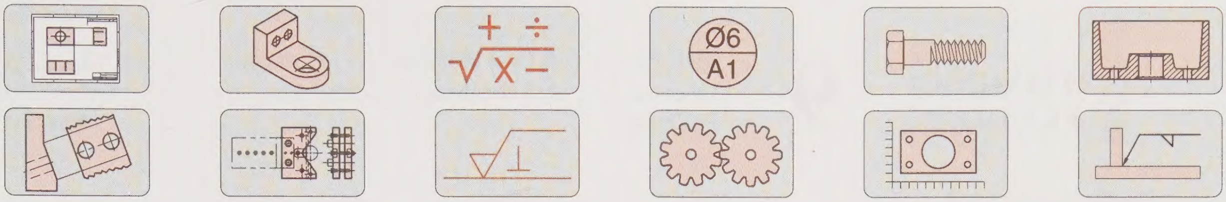
AMETEK, Inc., Houston Instrument Division
Carrier Corporation
Clausing Industrial
EZ Loader Boat Trailers, Inc.
The Falk Corporation
General Electric Co. U. S. A.
Girtz Industries, Inc.
The L. S. Starrett Company
Randall Machine Company
Skil Corporation
Toledo Scale Masstron Products
Worthington Industries Inc.

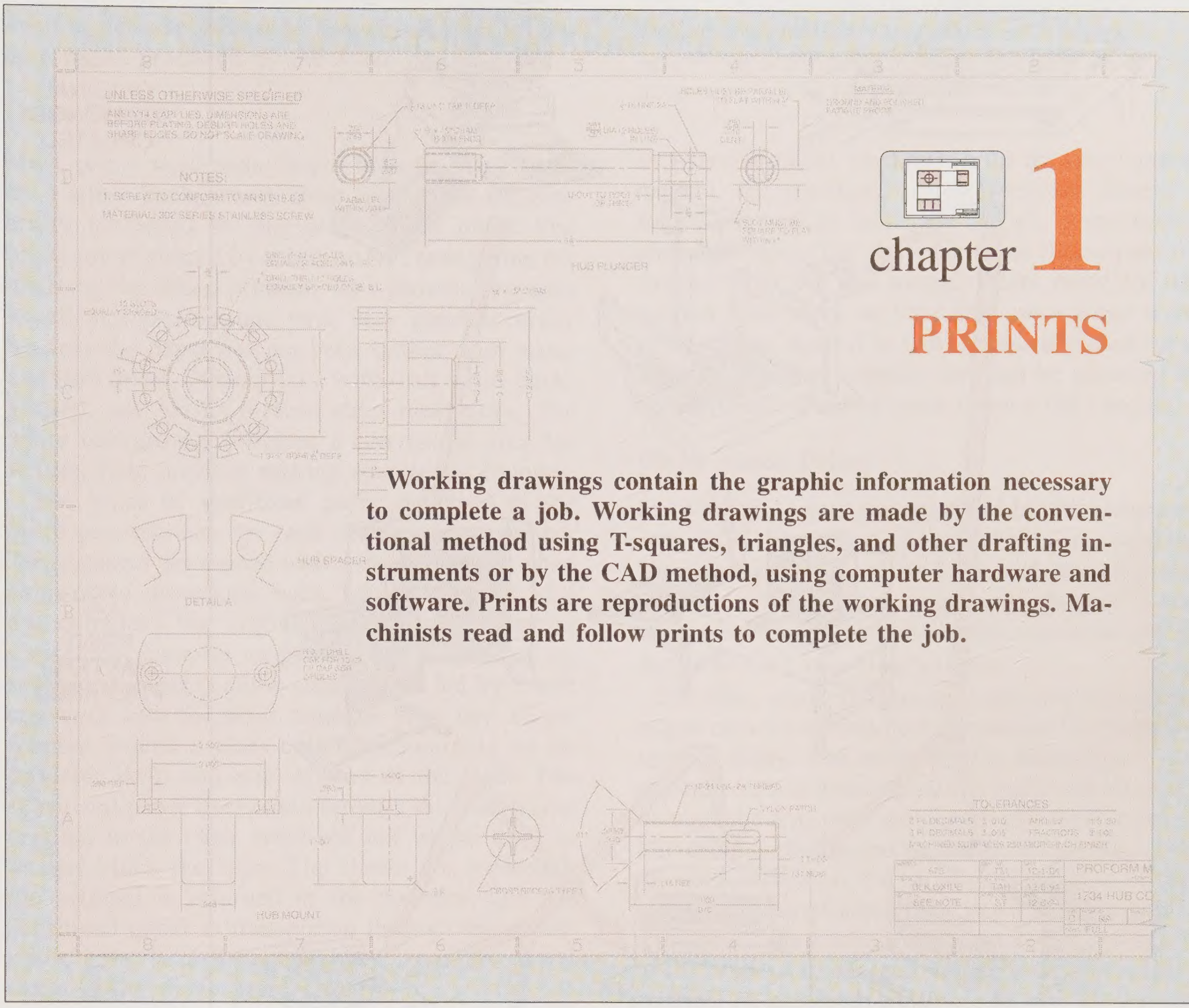
1 2 3 4 5 6 7 8 9 – 95 – 9 8 7 6 5 4 3 2 1

Printed in the United States of America

ISBN 0-8269-1864-6

Contents





chapter 1 PRINTS

Working drawings contain the graphic information necessary to complete a job. Working drawings are made by the conventional method using T-squares, triangles, and other drafting instruments or by the CAD method, using computer hardware and software. Prints are reproductions of the working drawings. Machinists read and follow prints to complete the job.

PRINTS

Prints are reproductions of working drawings. A *working drawing* is a set of plans that contains the information necessary to complete a job. Originally, prints were referred to as blueprints because the process used to make them produced a white line on a blue background. Any number of copies or blueprints could be made from working drawings by using a process similar to the process used for making prints of photographs.

Today, diazo prints are generally preferred over blueprints because of their white background and dark lines. Electrostatic prints are becoming increasingly popular due to their advantage of easy enlargement or reduction. See Figure 1-1.

Blueprints

The use of blueprints began in 1840 when a method was discovered to produce paper sensitized with iron salts that would undergo a chemical change when exposed to light. *Translucent paper* is paper that allows light to pass through. Drawings made on translucent paper were placed over the sensitized paper in a glass frame used to hold the paper firmly. The frame was then exposed to sunlight. A chemical action occurred wherever the light was permitted to strike the sensitized paper. When the blueprint paper was washed in water, the part protected by the pencil or ink lines on the tracing would show as white lines on a blue background. A fixing bath of potassium dichromate, a second rinse with water, and print drying completed the process. Blueprints are not common today.

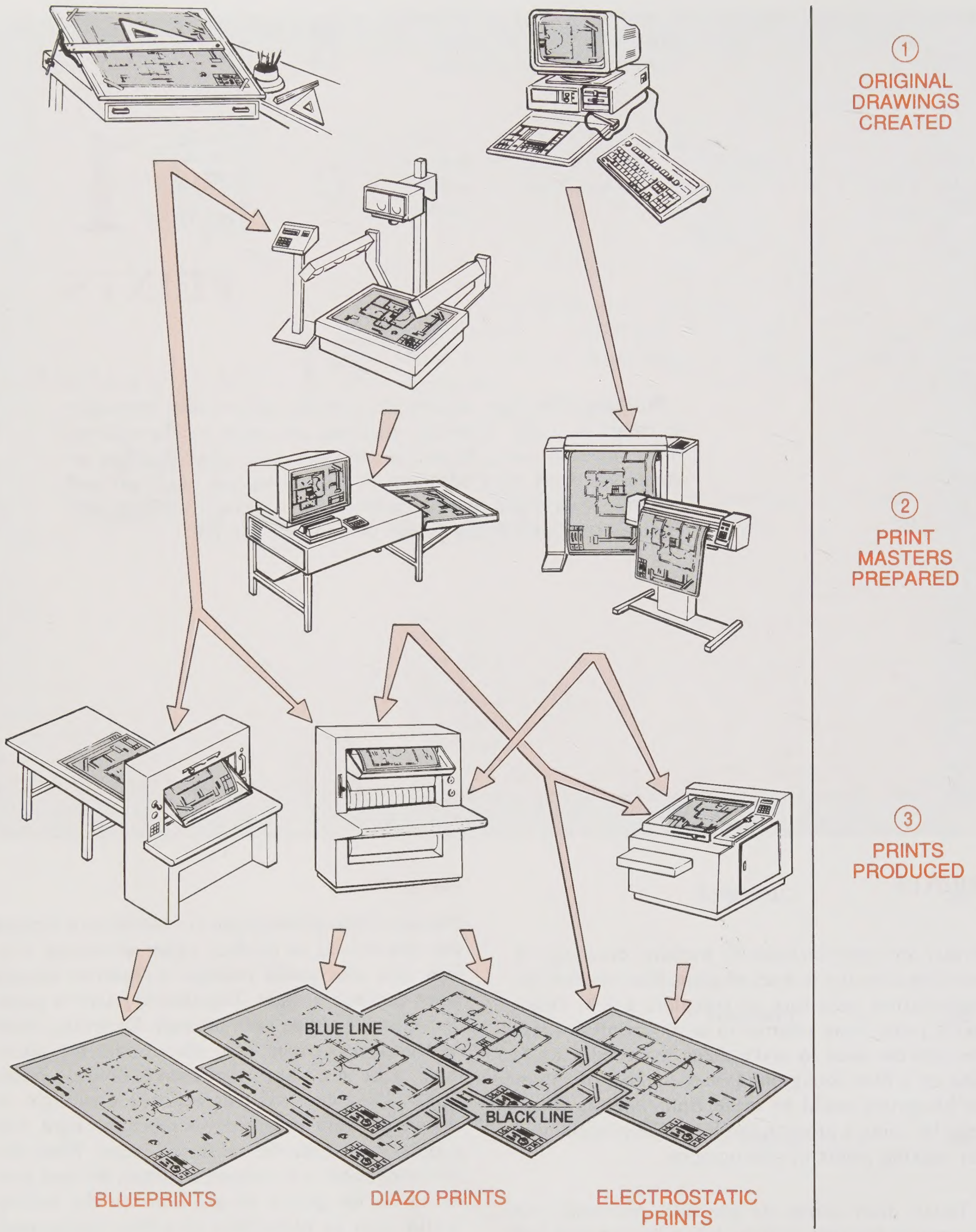


Figure 1-1. Prints are produced by the blueprint, diazo, or electrostatic process.

Blueprints are used in industries such as oil production because they fade less rapidly in sunlight than prints produced by the diazo process.

Diazo Prints

Most prints used today have blue or black lines on a white background. Blue line prints are generally preferred by engineers while black line prints are preferred by machinists. These prints are made by the diazo process. This process provides excellent reproductions with very good accuracy because the paper has not been soaked with water and then dried. Diazo prints, with their white background, are easier to read than blueprints. The white background provides a convenient area for writing field notes or making emergency changes.

Two types of sensitized paper are used in the diazo process, one for each development method. These papers are coated with a chemical that, when exposed to ultraviolet light, becomes a part of a dye complex. The original drawing, or a copy on translucent material, is placed over a sheet of the sensitized paper (yellow side) and is fed by a belt conveyor into the print machine. The two sheets revolve around a glass cylinder containing an ultraviolet lamp and are exposed to the light. The sensitized paper is exposed through the translucent original in the clear areas but not where lines or images block the light. The sheets are separated, the original is returned to the operator, and the sensitized paper is transported through the developing area. It is then developed by either a wet diazo or dry diazo process.

Wet Development Method. In the wet development method, the sensitized paper passes under a roller which moistens the exposed top surface completing the chemical reaction to bring out the image. Prints made by this method have black or blue lines on a white background.

Dry Development Method. In the dry development method, the sensitized paper is passed through a heated chamber in which its surface is exposed to ammonia vapor. The ammonia vapor precipitates the dye to bring out the image. Prints made by this method have black or blue lines on a white background. This method is most commonly used today since high-quality reproduction can be achieved on mylar (plastic film) or sepia (brown line) copies.

Electrostatic Prints

Electrostatic prints are produced by the same process used by office copiers. Full-size working drawings are exposed to light and are projected through a lens onto a negatively charged drum. They may be photographed with a camera and reduced to a 35 mm ($1\frac{3}{8}''$) frame.

The film, after processing, is inserted into an aperture card which can be keypunched for computer sorting, filing, and retrieval. The microfilm in the aperture card is then exposed to light and projected through the lens onto the negatively charged drum. The drum is discharged by the projected light from the nonimage areas but retains the negative charge in the unexposed areas. The drum then turns past a roller where black toner particles are attracted to the negatively charged image areas on the drum surface. As the drum continues to turn in synchronization with the positively charged copy paper, toner particles are attracted to the paper and fused to it by heat and pressure. See Figure 1-2.

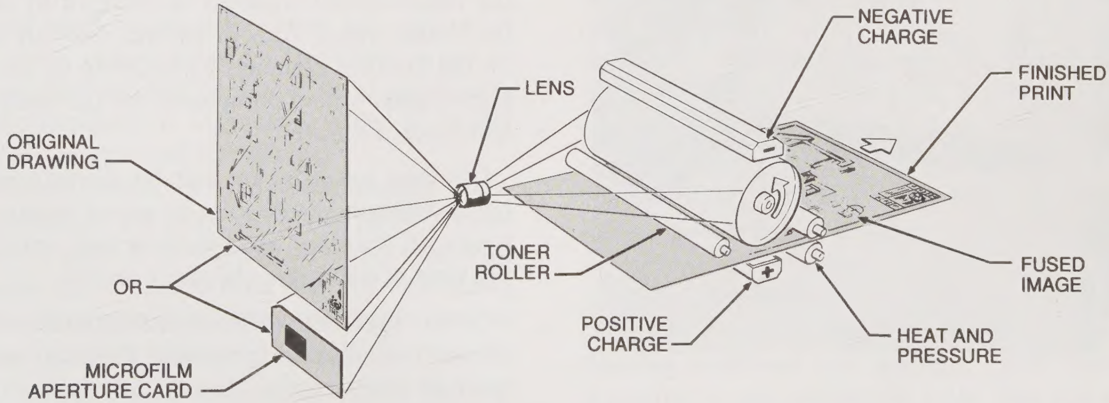


Figure 1-2. Electrostatic prints are produced as light is projected through a lens onto a negatively charged drum which offsets the image to positively charged paper.

Prints made by this method have black lines on a white background. The advantages of the electrostatic process include easy enlargement and reduction of drawings, small storage size, quick retrieval and duplication, and reduced shipping costs. The major disadvantage is the potential for distortion by projection through a lens.

CONVENTIONAL DRAFTING

Working drawings for prints may be made using conventional drafting practices or computer-aided design. *Conventional drafting practices* are a language of standard lines, symbols, and abbreviations used in conjunction with drafting principles so that drawings are consistent and easy to read. See ANSI Y series for additional information.

Basic tools are used to produce working drawings by the conventional method. These tools include T-squares, triangles, drafting instruments, scales, and pencils. See Figure 1-3.

Drafting machines (combination T-square, scale, and triangles) and parallel straightedges (combination drafting board and modified T-square) are commonly used in production situations. Drawings are begun after taping the drafting paper to the drafting board. All line work is done with construction lines that are darkened to produce the final drawing.

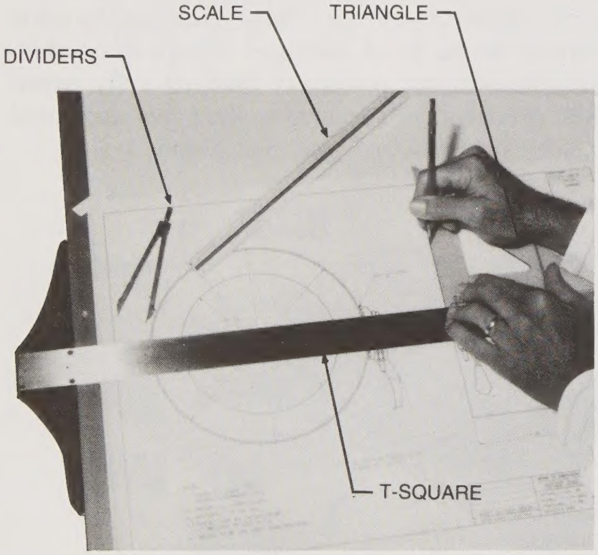


Figure 1-3. Conventional drafting tools include T-squares, triangles, instruments, scales, and pencils.

T-square

The T-square is used to draw horizontal lines and as a reference base for positioning triangles. The head of the T-square is held firmly against one edge of the board to ensure accuracy. T-squares are made of wood, plastic, or aluminum and are available in various lengths. The most popular T-squares are 24″ to 36″ in length.

Triangles

Triangles are used to draw vertical and inclined lines. The base of the triangle is held firmly against the blade of the T-square. Two standard triangles, 30°-60° and 45°, are available in a variety of sizes. Triangles are commonly made of clear plastic.

The 30°-60° triangle is used to produce vertical lines and inclined lines of 30° to 60° sloping to the left or right. The 45° triangle is used to produce vertical lines and inclined lines of 45° sloping to the left or right. The triangles may be used together to produce inclined lines every 15°. See Figure 1-4.

Drafting Instruments

Although a wide variety of precision drafting instruments is available, the compass and dividers are the most commonly used. Each of these is available in a variety of sizes. See Figure 1-5.

The compass is used to draw arcs and circles. One leg of the compass contains a needlepoint that is positioned on the centerpoint of the arc or circle to be drawn. The other leg contains the pencil lead used to draw the line. Two types of compasses are center-wheel and friction. The radius of the arc on the center-wheel compass is changed by adjusting the center wheel. Arcs of various radii are obtained on the friction compass by opening or closing the legs. Center-wheel compasses are the most popular and most accurate.

Dividers are used to transfer dimensions. Each leg contains a needlepoint to assure accuracy. Two types of dividers are center-wheel and friction. Friction dividers are the more useful.

Other drafting instruments include irregular (french) curves and templates. Irregular curves are used to draw curves that do not have consistent radii. Templates are used to save time when drawing standard items such as fasteners, springs, etc.

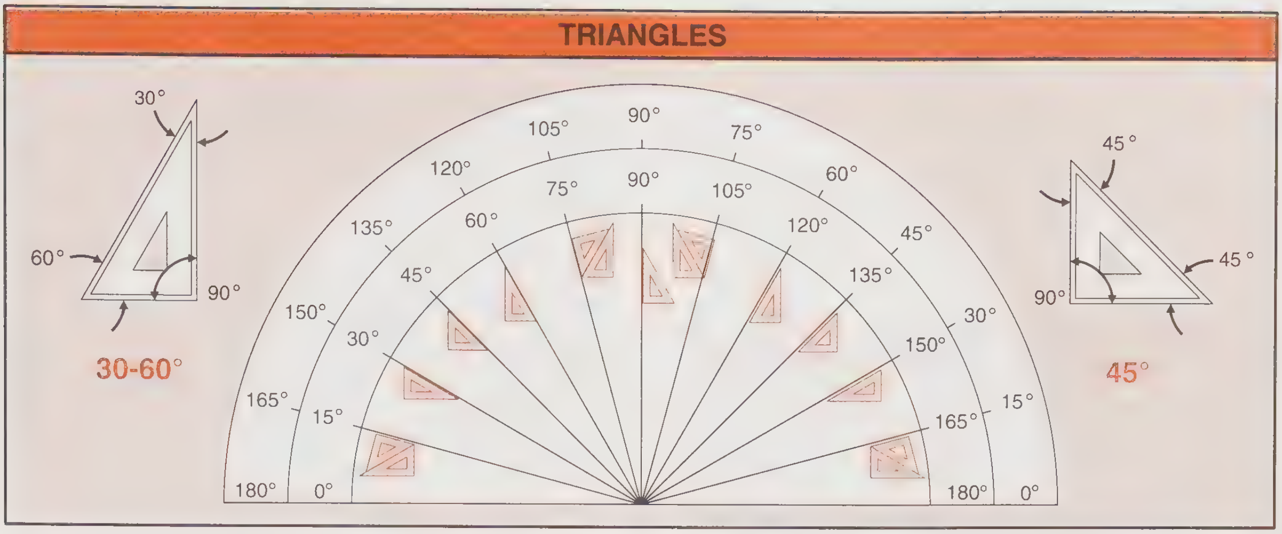


Figure 1-4. The 30°-60° and 45° triangles are used to draw lines 15° apart.

Figure 1-5. The compass is used to draw arcs and circles. The dividers are used to transfer dimensions.

Scales

Scales are used to measure lines and reduce or enlarge them proportionally. The three types of scales are the architect's scale, civil engineer's scale, and mechanical engineer's scale. A variety of sizes is commercially available.

An architect's scale is used when making drawings of buildings and other structural parts. A common type of scale is triangular in shape. One edge of the scale is a standard ruler divided into inches and sixteenths of an inch. The other edges contain 10 scales that are labeled 3, $1\frac{1}{2}$, 1, $\frac{3}{4}$, $\frac{1}{2}$, $\frac{3}{8}$, $\frac{1}{4}$, $\frac{3}{16}$, $\frac{1}{8}$, and $\frac{3}{32}$. The $\frac{1}{4}$ scale means that $\frac{1}{4}$″ = 1′-0″, and so forth. For larger scale drawings, the $1\frac{1}{2}$″ = 1′-0″, or 3″ = 1′-0″ scales are used.

The civil engineer's scale is used when making maps and survey drawings. Plot plans also may be drawn using this scale. The civil engineer's scale is graduated in decimal units. One inch units on the scale are divided into 10, 20, 30, 40, 50, or 60 parts. These units are used to represent the desired measuring unit such as inches, feet, or miles. For example, a building lot line that is 100′-0″ long drawn with the 20 scale (1″ = 20′-0″) measures 5″ on the drawing.

The mechanical engineer's scale is used when drawing machines and machine parts. This scale is similar to the architect's scale. The mechanical engineer's scale is divided into inches and fractional parts of an inch. The 16 scale is used to

layout full-size measurements. Each fractional part of the 16 scale is $\frac{1}{16}''$.

Drawings may also be drawn to $\frac{1}{2}$, $\frac{1}{4}$, or $\frac{1}{8}$ scale by using the appropriate scale. Full inch measurements are given on the scales. Fractional inch measurements are made between the zero and the end of the scale. See Figure 1-6.

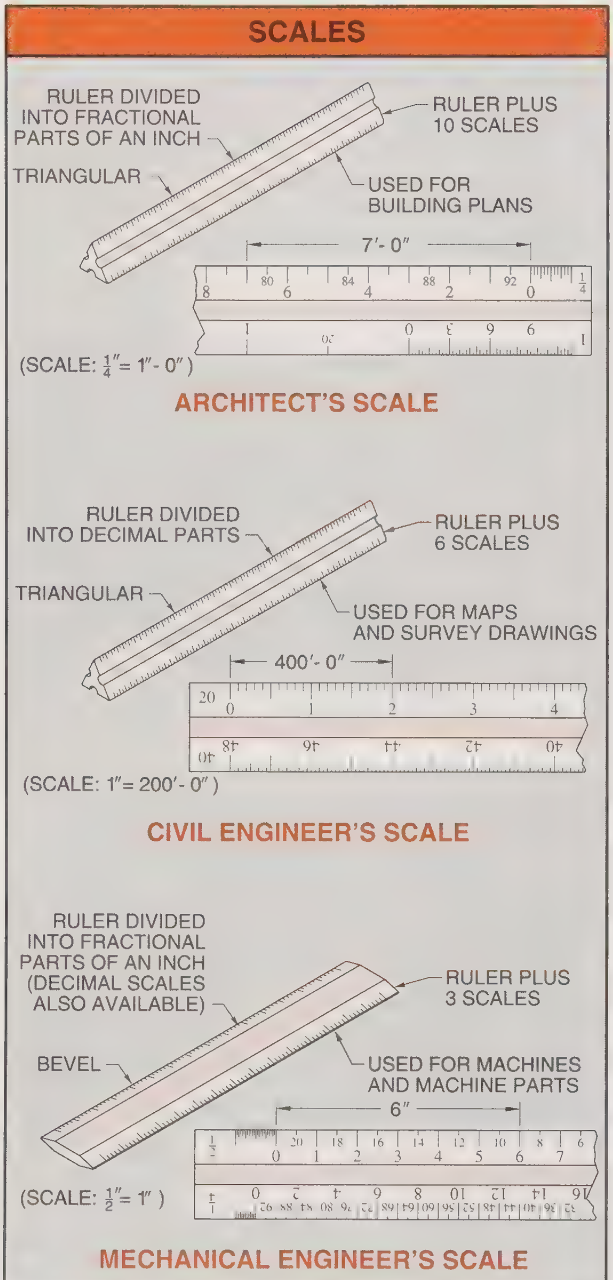


Figure 1-6. Three types of scales are used to produce scaled drawings.

Pencils

Wooden or mechanical pencils are used to draw lines. Wooden pencils contain a stamp near one end indicating the hardness or softness of the lead. The lead of desired hardness is inserted into mechanical pencils.

Hard leads are used to draw fine, precise lines. Medium leads are used to draw object lines. Soft leads are used primarily for sketching. Grades of lead range from 6B (extremely soft) to 9H (exceptionally hard). The engineer's range is HB, F, H, and 2H. F and H are most commonly used for producing drawings. See Figure 1-7.

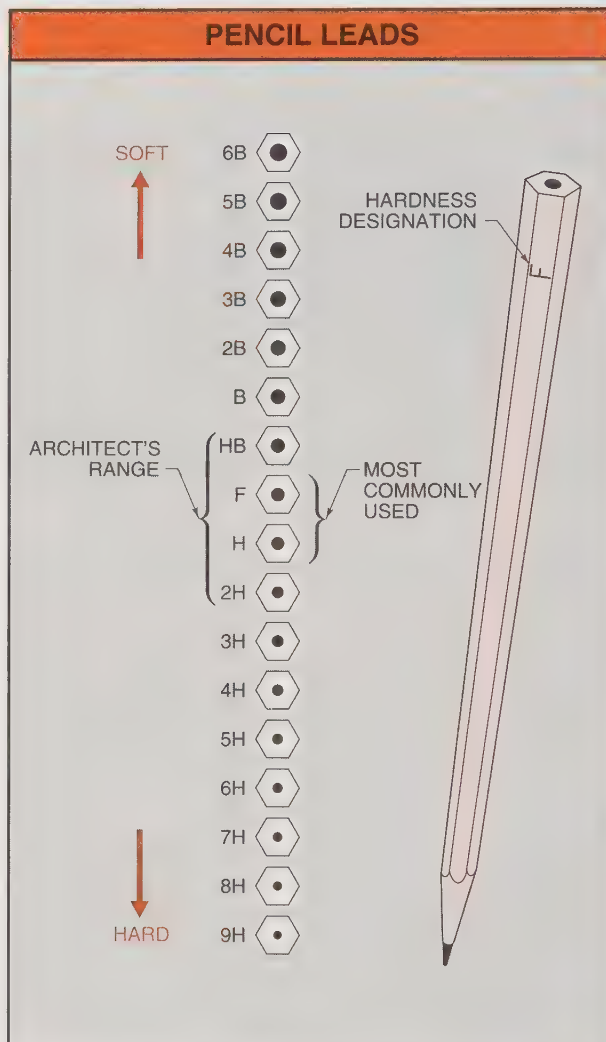


Figure 1-7. Pencil leads range from extremely soft to exceptionally hard.

COMPUTER-AIDED DESIGN (CAD)

Computer-aided design (CAD) is the generation and reproduction of line drawings and prints with computers. It is also known as computer-aided drafting, or computer-aided drafting and design (CADD). This system is popular in architectural and engineering offices.

Machinists reading CAD-generated plans benefit from the quality and consistency of line work, symbol representation, and lettering. Designers and engineers benefit from increased drafting productivity achieved in the planning, design, drafting, and reproduction of prints. See Figure 1-8.

Six primary factors contributing to increased productivity are Consistency, Changeability, Layering, Modeling, Storage, and Repeatability.

Consistency – constant sameness in line width, symbol depiction, and representation of drawing components.

Changeability – revisions, additions, and deletions are easily made.

Layering – a method, similar to using overlays on conventional drawings, in which base work is used to generate additional drawings.

Modeling – viewing of the complete part in pictorial form and subjection to stress tests.

Storage – drawings, stored on magnetic tapes or small magnetic disks, require minimal space.

Repeatability – an unlimited number of sheets may be reproduced, each with original quality.

CAD systems use hardware and software to generate drawings. *Hardware* is the physical components of a computer system, including input devices, central processing unit (CPU), and output devices.

A large variety of commercially available components are used to control, manage, and process information in CAD systems. See Figure 1-9. *Software* is the operating system of a computer, on magnetic tape or disks, that provides operational instructions for capturing and formatting keystrokes and generating lines. Software allows system hardware components to interact in the production of drawings. See Figure 1-10.

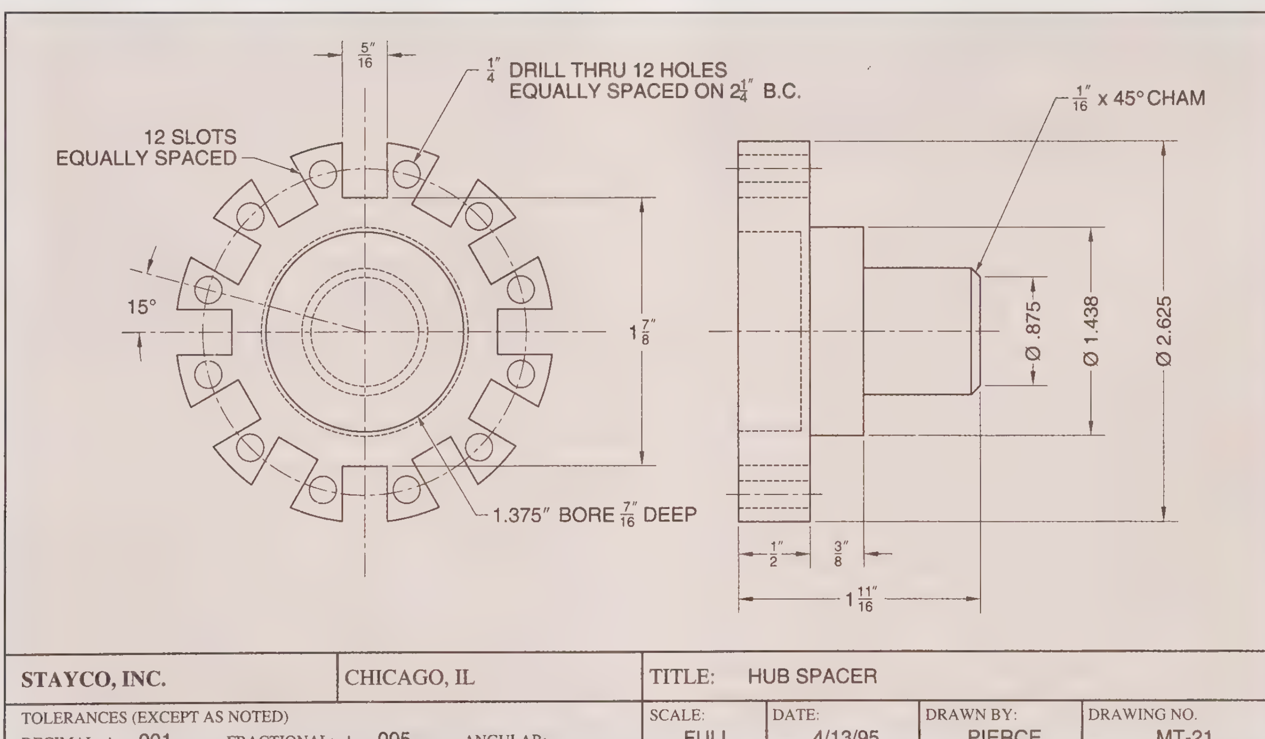


Figure 1-8. CAD systems produce excellent quality drawings consistently.

Figure 1-9. Hardware components of a CAD system are the input devices, central processing unit, and output devices.

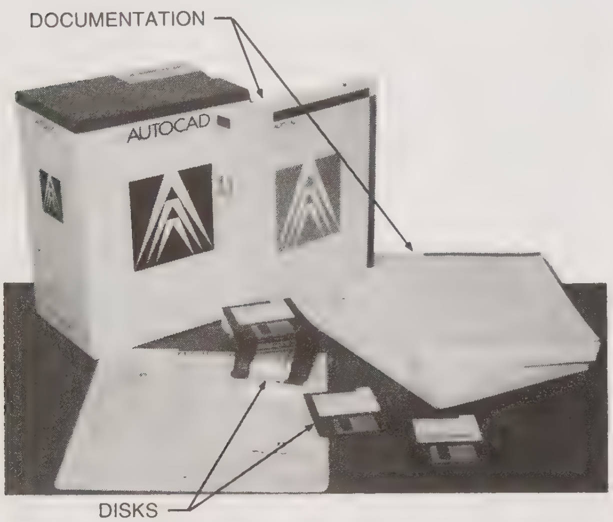


Figure 1-10. Software is the operating system that provides instructions to the hardware components.

Input Devices

Input devices are hardware used to enter information into a computer system. The input devices are interfaced (connected) with the central processing unit, which controls the CAD system. Information may be input by the use of electronic or electromechanical devices. Electronic devices use electronic signals to relay information to the CPU. Electromechanical devices use mechanical actuation to input electronic information. Common input devices include the graphics tablet, digitizing tablet, keyboard, and light pen. Tablet accessories include the stylus, mouse, joystick, thumbwheel, and trackball.

Graphics Tablet. A graphics tablet is a common input device used with a CAD system. It consists of a drawing area and a menu. See Figure 1-11. The menu is a group of commands. Menu selections may consist of simple commands such as inserting circles and erasing lines, or more complex operations such as drawing tangent lines and dimensioning objects.

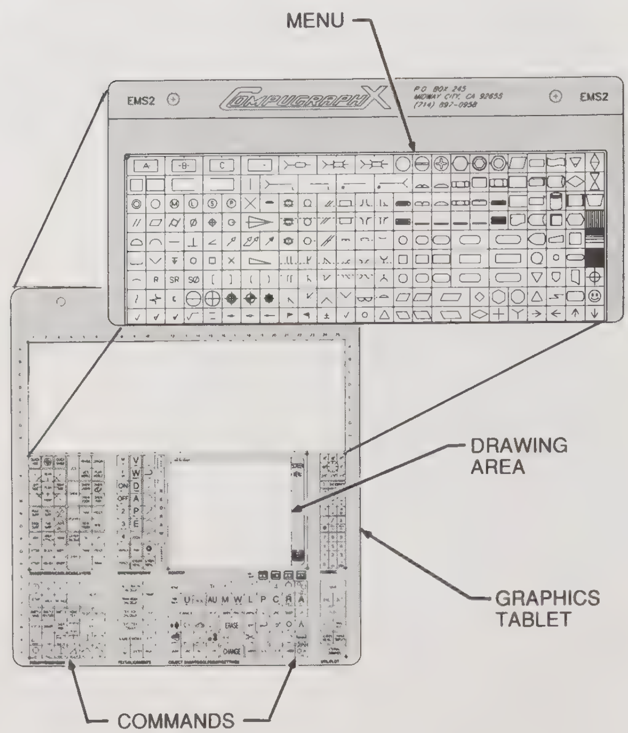


Figure 1-11. A graphics tablet consists of a group of commands and a drawing area.

An electronic or electromechanical device is used with the graphics tablet to choose a function from the menu and "draw" the object in the space provided. For example, a CAD operator may choose "Circle" from the Compugraphx menu with a stylus (pen-like device). The stylus is placed in the drawing area and a cursor on the display screen shows its present location. A *cursor* is the solid or flashing pointer indicating position of work. As the stylus is moved to its desired location, the cursor moves accordingly. Once in position, the size of the circle may be input by using the keyboard or stylus.

In addition to standard commands, the graphics tablet may display a library of symbols. Common symbols include weld symbols, surface finish, geometric tolerance, ANSI dimension, fasteners, set

screws, rivet pins, etc. A symbol that is frequently used, but not part of the original symbols library, can be created and stored. When needed again, the symbol can be recalled from the library and inserted in its desired location. For example, a recurring bolt head symbol could be created, stored, recalled, and inserted as often as needed.

Digitizing Tablet. A larger version of the graphics tablet, known as a digitizing tablet, can be used to convert existing drawings to CAD without reinputting all drawing components. An existing print is placed on the digitizing tablet and digitized (traced) with a stylus or mouse. The digitized drawing is then treated as other CAD drawings and may be revised to required specifications. See Figure 1-12.

Figure 1-12. A digitizing tablet is used to convert existing drawings to a CAD format.

Keyboard. A *keyboard* is an electronic device that sends signals to the CPU. The keyboard is the most common input device. The number and letter arrangement is similar to a typewriter. For example, the standard QWERTY letter arrangement is used in addition to function keys. A *function key* is a key that performs a particular function when depressed. For example, a function key labeled Delete will delete highlighted keystrokes.

The keyboard has the capability of inputting notes and dimensions as well as positioning the cursor on the display monitor. A keyboard may be the sole input device or it may be used in conjunction with other input devices.

Light Pen. A *light pen* is a photosensitive electronic device used to enter data into the computer. Data (information) is input when the tip of the light pen is pressed directly on the video display screen. The operator may chose various commands listed along the edge of the screen in the same manner as when using a graphics tablet. An advantage of using the light pen is that the operator is working directly on the drawing rather than indirectly, as with the graphics tablet.

Tablet Accessories. A stylus, mouse, joystick, thumbwheels, and trackballs are common accessories used in conjunction with tablets to input information. These accessories are either electronically or electromechanically operated.

A *stylus* is an electromechanical device used to input information into the computer. The stylus is used to select commands from the menu and position the cursor in the required area. When the desired command or position is located, the tip of the stylus is depressed against the surface of the tablet. As the tip is depressed, the stylus relays an electronic signal to the CPU.

A *mouse* is an electronic device used to input information into the computer. A mouse may be interfaced with a tablet or used separately. When used separately, the mouse controls the cursor on the display screen through movement on a hard surface. Menu selections are made by moving the cursor to the edge of the display screen and selecting the desired command.

A *joystick* is an electromechanical device used to control the cursor on the display screen and enter information into the computer. It may be used to choose a command from the display screen and locate its position on the drawing area.

A *thumbwheel* is an electromechanical device used to control the position of the cursor in vertical and horizontal planes. Two thumbwheels are required. One thumbwheel controls the vertical movement and the other controls the horizontal movement of the cursor.

A *trackball* is an electromechanical device similar to a thumbwheel in that it is only used to control cursor movement. A single trackball controls both the horizontal and vertical movement of the cursor and also has the capability of moving it diagonally.

The cursor is moved by rolling the trackball in the desired direction.

Central Processing Unit

The *central processing unit (CPU)* is the control center of the computer. It receives information through the input devices and produces an output image. A CPU is classified by its memory capacity and the speed at which it carries out commands. A larger memory capacity generally has a greater capability of producing quality drawings. The central processing unit stores information through the use of magnetic tapes, disks, and internal memory. CPUs may be dedicated for CAD systems only or may also run other software, such as word or data processing programs.

Output Devices

Output devices are hardware that either display or generate drawings. The basic types of output devices are monitors (screens), printers, and plotters.

Monitor. A *monitor* is a video display terminal. A monitor is a necessity for all CAD stations. The monitor displays the drawing that the operator is developing. Monitors are available in many sizes and are chosen based upon the application. A large monitor may be required when using a light pen because the large working surface enables an operator to work more accurately with the drawing. On some types of CAD systems two monitors are used. One monitor displays the drawing and the other displays the menu.

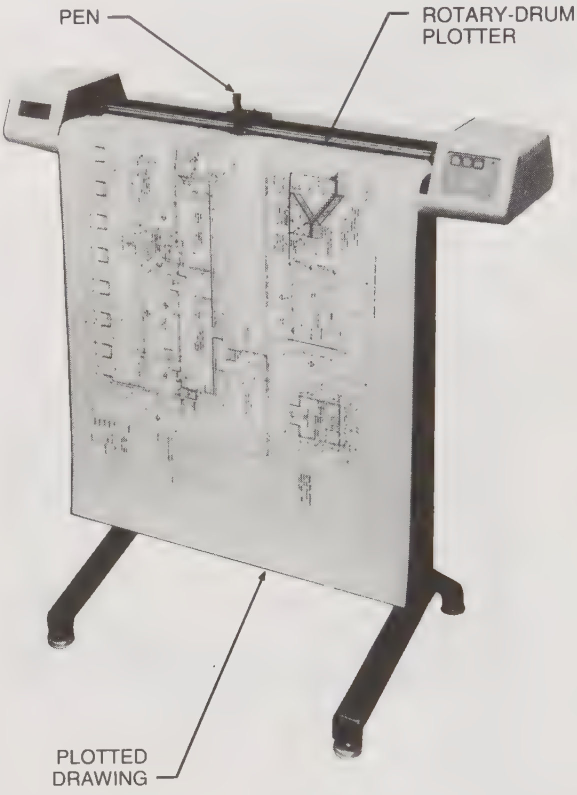
Printer. Printers produce drawings on paper. They provide a fast and convenient method of checking the placement of drawing features. The drawing generated by a printer consists of small dots (dot matrix) or a laser-generated image. The copy produced by a printer is generally of less-than-desirable quality. Consequently, final drawings are seldom produced by a printer.

Plotter. A *plotter* is an output device that generates finished drawings with pens. Plotters are commercially available with single-color or multiple-color pens. See Figure 1-13.

The quality of a plotted drawing is much better than a printed drawing. Plotters vary in size and are chosen based upon the application. Larger plotters have the capability of plotting E-size sheets of paper or film. Plotters are available in two major styles: rotary-drum and flatbed plotters.

On a rotary-drum plotter, the paper is mounted on a drum and moves with the drum's rotation. The pen moves parallel with the length of the drum. Vertical lines are drawn with the drum remaining in a fixed position while the pen moves along the sheet of paper. Horizontal lines are drawn with the pen remaining stationary and the drum rotating.

A flatbed plotter allows the piece of paper to lie flat on its bed. The pen moves along the width and height of the paper while the paper remains stationary.



AMETEK, Inc., Houston Instrument Division

Figure 1-13. A plotter produces high-quality drawings.

PRINTS

Working drawings are commonly produced on film or paper. The working drawings are copied to produce prints. The two basic materials used for working drawings are polyester and vellum. Prints are

produced on various sizes of paper depending upon the scale used and the complexity of the part being drawn. By using standard size paper for drawings, basic formats, title blocks, revision blocks, parts list, supplementary blocks, and drawing numbers can be utilized per ANSI standards.

Polyester

Polyester film provides good surfaces for drafting requirements. Ink lines are smooth, black, and consistent. Pencil lines are uniform in density and continuity. Polyester film is available in sheets and rolls punched for specific plotters.

Polyester film may have a matte finish on one or both sides. A *matte finish* is a dull finish that will accept and hold pencil and ink lines well. Polyester film may be purchased in 20 yd and 50 yd rolls and standard size flat sheets. The thickness varies from .002″ to .007″.

Vellum

Vellum is a translucent paper made from a rag base. A *translucent* paper allows light to pass through. Vellum does not yellow, become brittle, or deteriorate with age. It can be used for pencil or ink lines. Erasures are easily made and do not reproduce. Vellum is available in sheets, rolls, and rolls punched for specific plotters. It may be purchased in 10, 50, or 100 flat-sheet packages and in 20 yd and 50 yd rolls. The thickness varies from .0025″ to .0030″.

Paper Sizes

USA flat and roll sheets are standardized by ANSI Y14.1. Flat sheets are designated by the letters A through F. Rolls are designated by the letters G, H, J, and K. The lower the letter in the alphabet, the smaller the paper size. Margins are sufficiently large enough to allow reproductions of drawings made to these standard sizes and to international paper sizes. See Figure 1-14.

International paper sizes are given by letter-number combinations. The length of an international sheet is found by multiplying the width by the $\sqrt{2}$. The $\sqrt{2}$ is 1.414 ($1.414 \times 1.414 = 1.999 = 2$). For example, the length of an A3 size sheet is 420 mm ($297 \times 1.414 = 419.958 = 420$ mm). See Figure 1-15.

USA PAPER SIZES*

FLAT SHEETS

SIZE	WIDTH	LENGTH
A	8.5	11
B	11	17
C	17	22
D	22	34
E	34	44
F	28	40

ROLLS

SIZE	WIDTH	LENGTH	
		MIN	MAX
G	11	22.5	90
H	28	44	143
J	34	55	176
K	40	55	143

*All measurements are in inches.

Figure 1-14. Standard USA paper sizes are designated by letters.

INTERNATIONAL PAPER SIZES*

SIZE	WIDTH	LENGTH	NEAREST USA SIZE
A4	210	297	A
A3	297	420	B
A2	420	594	C
A1	594	841	D
A0	841	1189	E

*All measurements are in millimeters.

FINDING LENGTH

$L = W \times \sqrt{2}$

where

L = length W = width $\sqrt{2} = 1.414$

What is the length of an A4 sheet?

$L = W \times \sqrt{2}$

$L = 210 \times 1.414 = 296.94 = 297$

L = **297 mm**

Figure 1-15. Standard international paper sizes are designated by letter-number combinations.

Basic Formats

Drawing paper is oriented with its base horizontal along the long dimension with the exception of A size vertical paper. The borderline is thick (approximately .030″). The vertical margins between the edges of the paper and the border line vary from .25″ to 1.00″ depending on the paper size. The horizontal margins vary from .38″ to 1.00″ depending on the paper size. See Figure 1-16.

Lettering. Lettering size and style is per ANSI Y14.2M. Uppercase, single-stroke gothic letters are used. They may be inclined or vertical. The preferred slope for inclined letters is 68° with the horizontal. The height of freehand lettering varies from .120″ to .290″ depending on the paper size.

Zoning. Drawing paper in flat sheets and rolls may include zones for reference purposes. Zones are referenced by alphabetical and numerical entries in margins. Commonly, the numerical entries are along the base of the paper and the alphabetical entries are along the right and left hand margins. The sizes of the individual zones vary based upon the paper size.

Title Blocks

Title blocks are located in the lower right-hand corner of the drawing sheet. Title blocks are often customized to the individual company. Information common to all drawings is located in the title block. Two basic title blocks are given; one for sheet sizes A, B, C, and G and the other for sheet sizes D, E, F, H, J, and K. The basic difference between the two sizes is the dimensions of the various blocks. See Figure 1-17. See Figure 1-18.

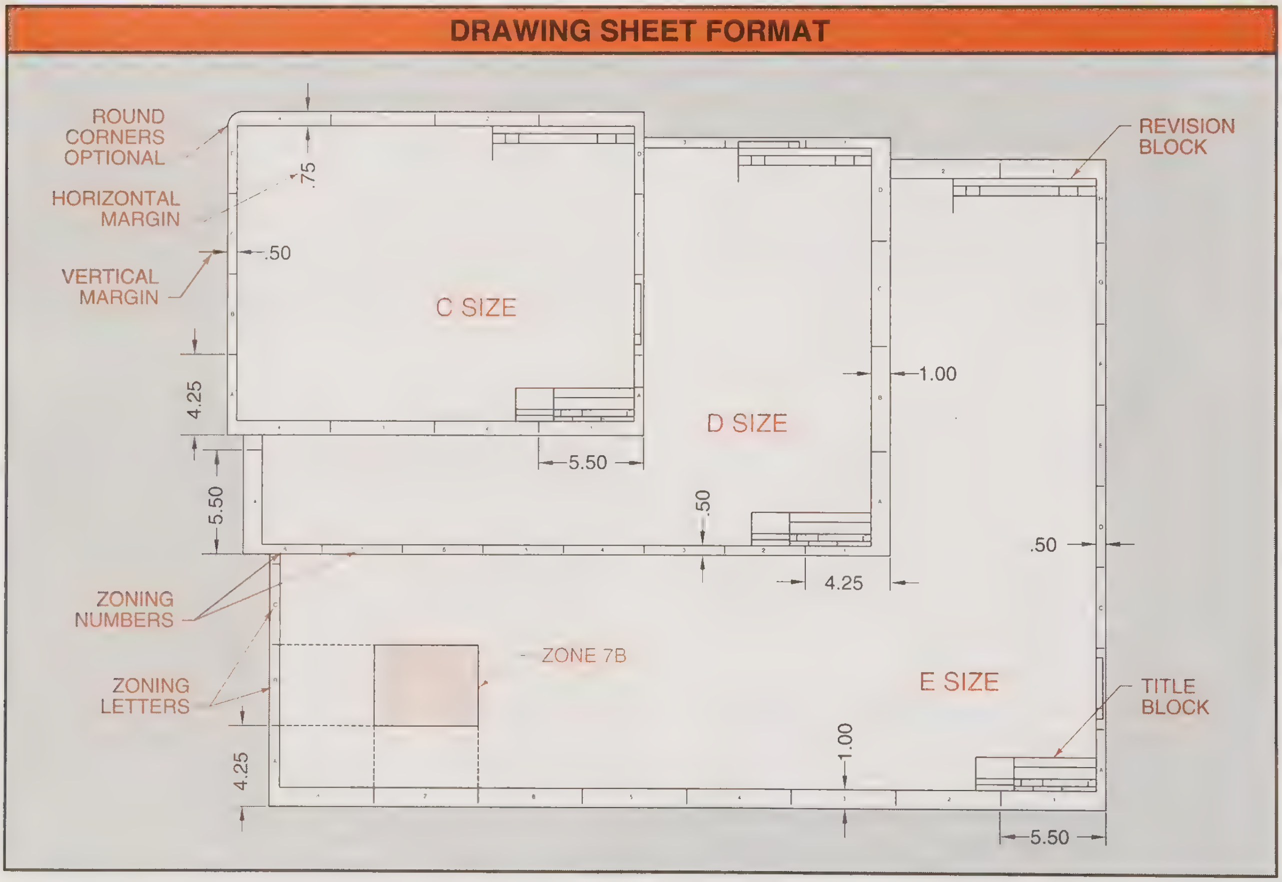


Figure 1-16. The basic format of drawing sheets includes the title block, margins, and zoning.

FSCM is the acronym for Federal Supply Code for Manufacturers. This code identification number is a five-digit numerical code that applies to all organizations that either have or are producing items used by the United States government. FSCM numbers are entered in the appropriate block of the title block format.

Revision Block. Revision blocks are located in the upper right-hand corner of the sheet. They are extended downward as required. The revision symbol, description of the change authorization document, date, and approvals are included. A zone column is added if required. The width of revision blocks may be changed to provide for other columns as necessary. See Figure 1-19.

Parts List. The parts list is also known as a bill of materials. It is located in the lower right-hand corner of the sheet above the title block. Supplementary parts lists may be located to the left of the original parts list. The parts list contains the name of the part, the identifying number if required, and how many are required.

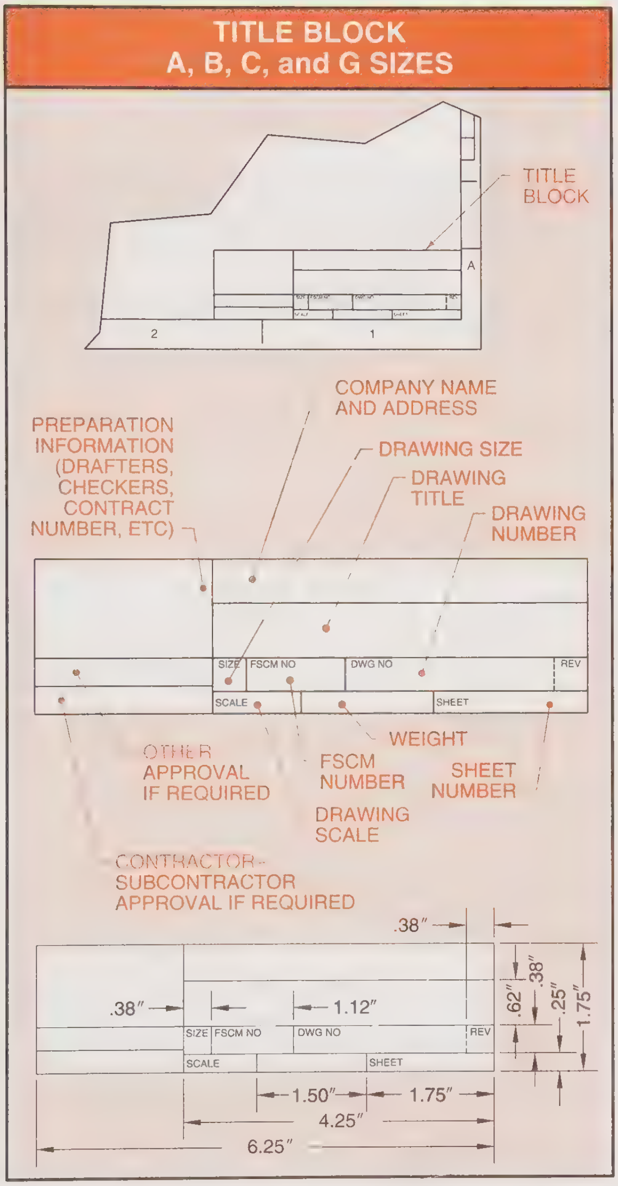


Figure 1-17. Title blocks for sheet sizes A, B, C, and G are 1.75″ x 6.25″.

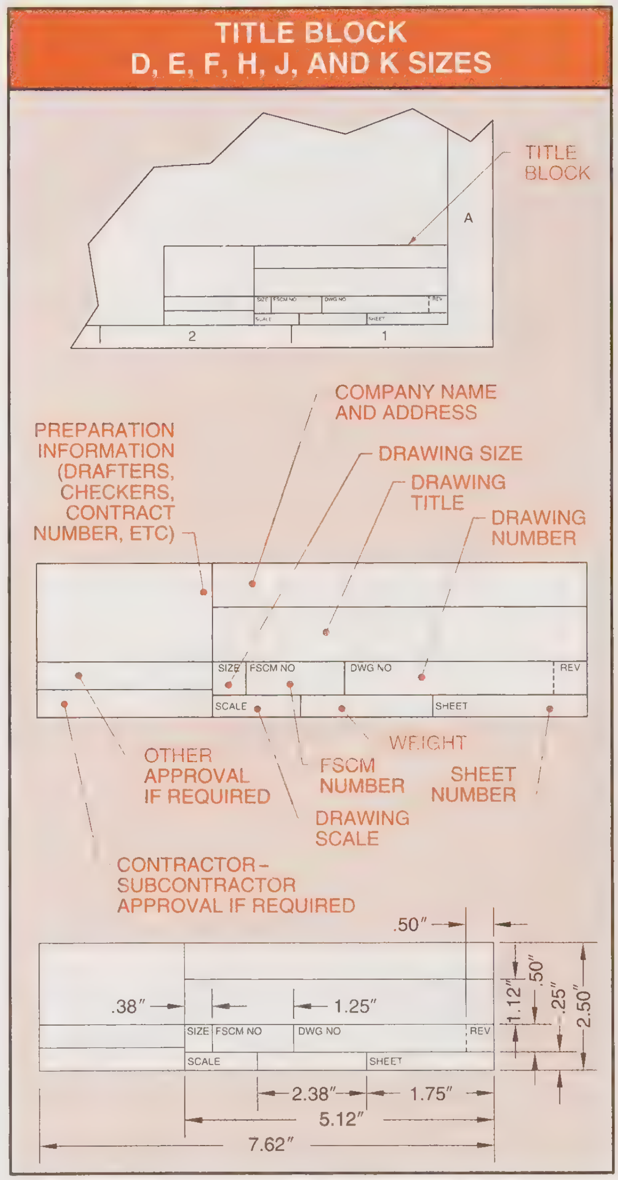


Figure 1-18. Title blocks for sheet sizes D, E, F, H, J, and K are 2.50″ x 7.62″.

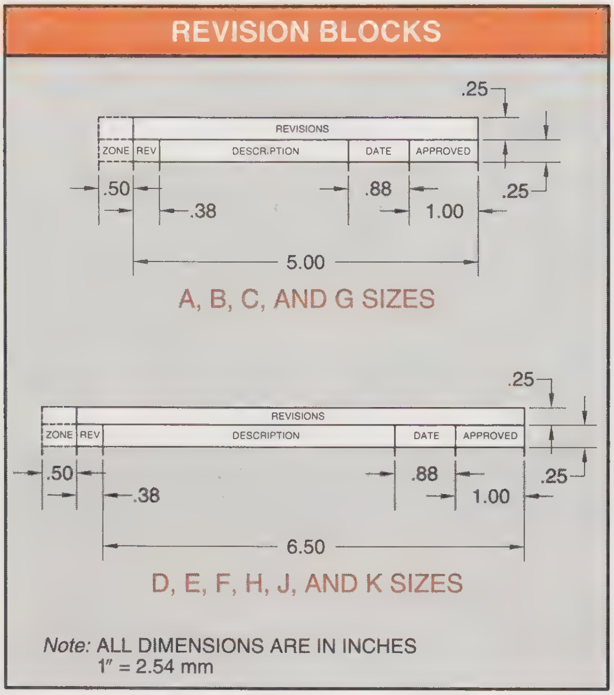


Figure 1-19. Revision blocks are located in the upper right-hand corner of the sheet.

Supplementary Blocks. Supplementary blocks contain additional information such as dimensioning and tolerancing notes, material, finish, etc. These blocks are located to the left of the title block. Additional supplementary blocks may be added as required. See Figure 1-20.

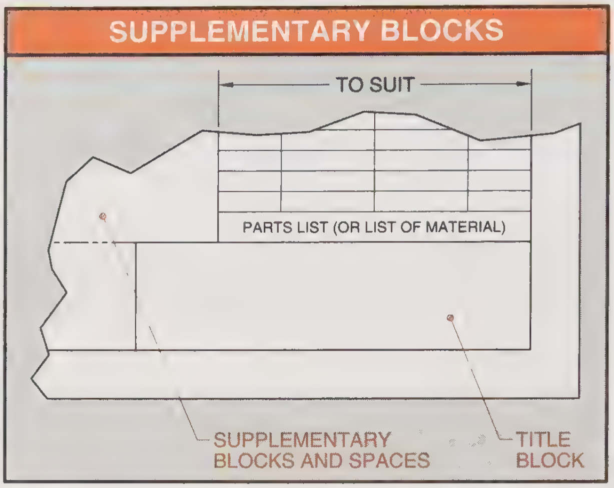


Figure 1-20. Supplementary blocks are located to the left of the title block.

Review Questions

Name ______________________________ Date ______________

Matching — Angles

______ 1. 135°

______ 2. 120°

______ 3. 165°

______ 4. 75°

______ 5. 30°

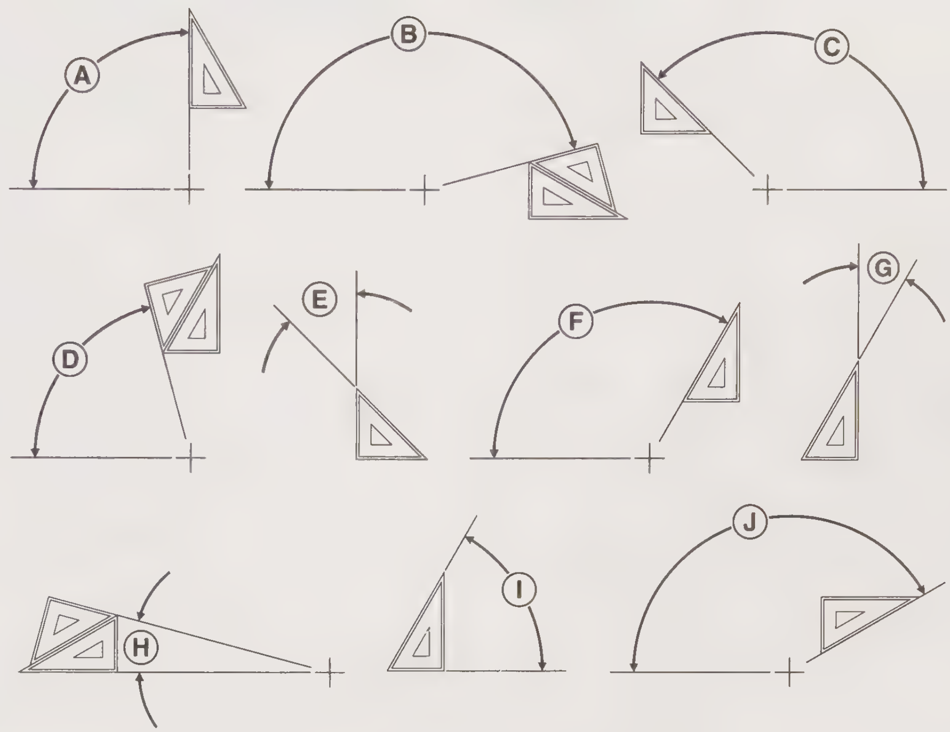
______ 6. 45°

______ 7. 90°

______ 8. 150°

______ 9. 60°

______ 10. 15°



Completion

______ 1. Electrostatic prints have ______ lines on a white background.

______ 2. T-squares, triangles, drafting instruments, etc. are used to produce drawings by the ______ method.

______ 3. Triangles may be used together to produce inclined lines every ______°.

______ 4. The ______ is an instrument used to draw arcs and circles.

______ 5. The ______ engineer's scale is used when drawing machines and machine parts.

______ 6. ______ is the operating system of a computer.

______ 7. The keyboard is an electronic device that sends signals to the ______ of a computer.

______ 8. ______ drawings are commonly produced on film or paper.

______ 9. A(n) ______ finish on paper is a dull finish.

_____ 10. The preferred slope for inclined letters is _____° with the horizontal.

_____ 11. _____ are used to draw vertical and inclined lines.

_____ 12. The _____ engineer's scale is used when making maps and survey drawings.

_____ 13. A thumbwheel controls the vertical and horizontal movement of the _____.

_____ 14. Vellum may be purchased in 20 yd or _____ yd rolls.

_____ 15. Lettering size and style on drawings is established per _____ Y14.2M.

Multiple Choice

_____ 1. Revision blocks _____.

A. are 5″ long for A, B, C, and G sizes
B. may be extended if a zone is required
C. both A and B
D. neither A nor B

_____ 2. Blueprints are used in some industries today because they _____ than other prints.

A. are less expensive
B. are easier to produce
C. fade less rapidly in sunlight
D. all of the above

_____ 3. The most popular T-squares are _____ in length.

A. 12″ to 24″
B. 18″ to 24″
C. 18″ to 30″
D. 24″ to 36″

_____ 4. The _____ scale contains a standard 12″ ruler and 10 scales.

A. architect's
B. civil engineer's
C. drafter's
D. assembler's

_____ 5. Vertical margins between the edges of drawing paper and the border line vary from _____ depending on the paper size.

A. .10″ to .20″
B. .15″ to .25″
C. .25″ to 1.00″
D. .25″ to 1.25″

_____ 6. The computer keyboard contains function keys and the standard _____ letter arrangement.

A. POINT
B. XYZ
C. ALPHA
D. QWERTY

_____ 7. USA flat and roll sheets of paper are designated for size by _____.

A. letters
B. numbers
C. both A and B
D. neither A nor B

_______ **8.** International flat and roll sheets of paper are designated for size by _______.

A. letters
B. numbers
C. both A and B
D. neither A nor B

_______ **9.** Zones on drawing paper are referenced by _______ entries in the margins.

A. alphabetical
B. numerical
C. both A and B
D. neither A nor B

_______ **10.** The length of an international sheet of paper is found by _______.

A. adding 250 mm to the width
B. multiplying the width by 3
C. multiplying the width by the $\sqrt{2}$
D. none of the above

_______ **11.** Blue line prints on a white background are made today by the _______ process.

A. diazo
B. electrostatic
C. both A and B
D. neither A nor B

_______ **12.** Dividers are drafting instruments used to _______.

A. draw arcs
B. draw circles
C. transfer dimensions
D. transfer letters

_______ **13.** The civil engineer's scale is graduated in _______.

A. inches and sixteenths of an inch
B. decimal units
C. both A and B
D. neither A nor B

_______ **14.** _______ is the physical components of a computer system.

A. Software
B. Hardware
C. CAD
D. CADD

_______ **15.** The _______ of a CAD system is a group of commands.

A. output device
B. digitizer
C. cursor
D. menu

_______ **16.** The acronymn FSCM refers to the _______.

A. First Standard Code for Manufacturers
B. Federal Standard Code for Manufacturers
C. First Supply Code for Manufacturers
D. Federal Supply Code for Manufacturers

_______ **17.** The T-square is used _______.

A. to draw horizontal lines
B. as a reference for triangles
C. both A and B
D. neither A nor B

_______ **18.** _______ is a translucent paper made from a rag base.

A. Vellum
B. Polyester
C. either A or B
D. neither A nor B

True-False

T F 1. Prints are originals of working drawings.

T F 2. Diazo prints have dark lines on a white background.

T F 3. The T-square is a drafting instrument used to draw horizontal lines.

T F 4. A translucent sheet stops light from passing through.

T F 5. Hard pencil leads are used to draw object lines.

T F 6. Information may be input into computers by the use of electronic or electromechanical devices.

T F 7. A monitor is an input device.

T F 8. Vellum is made from a rag base.

T F 9. The parts list on a print is located above the title block.

T F 10. Plotters generate finished drawings by a photographic process.

T F 11. The majority of prints used today have blue or black lines on a white background.

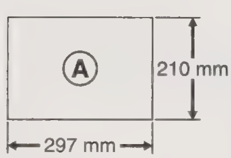
T F 12. Friction compasses are more accurate than center-wheel compasses.

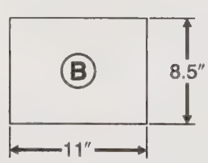
T F 13. A pencil lead labeled 6B is exceptionally hard.

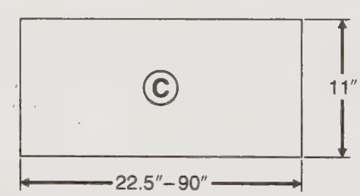
T F 14. A digitizing tablet is an input device.

T F 15. Revision blocks may be extended downward if necessary.

Matching — Paper Sizes







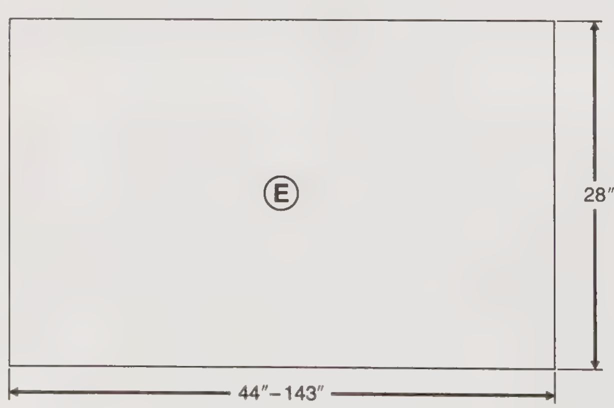
_____ 1. A sheet

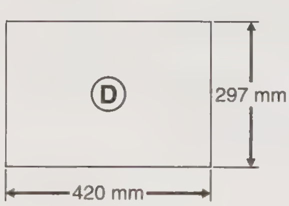
_____ 2. A3 sheet

_____ 3. A4 sheet

_____ 4. G roll

_____ 5. H roll





◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

<table>
<tr><td>DRAFTER
RJH</td><td>DATE
5-2-95</td><td colspan="5">PIERCE FIXTURE COMPANY
CHICAGO, ILLINOIS</td></tr>
<tr><td>CHECKER
TAJ</td><td>DATE
5-9-95</td><td colspan="5" rowspan="2">CENTERING FIXTURE</td></tr>
<tr><td>APPROVAL
CT</td><td>DATE
5-17-95</td></tr>
<tr><td colspan="2"></td><td>SIZE
C</td><td>FSCM NO
NA</td><td colspan="2">DWG NO
316915</td><td>REV</td></tr>
<tr><td colspan="2"></td><td colspan="2">SCALE 1/4" = 1'-0"</td><td></td><td colspan="2">SHEET 1 OF 3</td></tr>
</table>

TITLE BLOCK 1

Title Block 1

________ 1. The scale of the drawing is ________" = 1'-0".

________ 2. There are ________ sheets in this set of prints.

________ 3. The drawing number is ________.

T F 4. The drawing was drawn and checked by the same person.

________ 5. Prints for this drawing are reproduced on size ________ sheets.

T F 6. The FSCM number is required for this drawing.

T F 7. Approval of the drawing was made by TAJ.

________ 8. Approval of the drawing was completed on ________-95.

________ 9. The title of the part to be fabricated is ________.

T F 10. Pierce Fixture Co. is located in Detroit, Michigan.

________ 11. This sheet is Sheet ________.

T F 12. This particular drawing has been revised.

________ 13. The drafter for the drawing was ________.

________ 14. The drawing was checked on ________-95.

T F 15. Checking and approval of the drawing were completed on consecutive days.

LH Turret Ass'y.

________ 1. The drawing was drawn by ________.

________ 2. Drawing approval was completed on ________-95.

________ 3. The tolerance for three-place decimal dimensions is ±________″.

________ 4. The drawing is drawn to ________ scale.

________ 5. Unless otherwise specified, all sharp edges are to be broken a maximum of ________″.

________ 6. Sheet ________ of 6 is shown.

________ 7. ________ gave approval for the Engineering Department.

________ 8. Randall Machine Co. is located in ________, OH.

________ 9. The part shown is a(n) ________.

________ 10. The print is on a size ________ sheet.

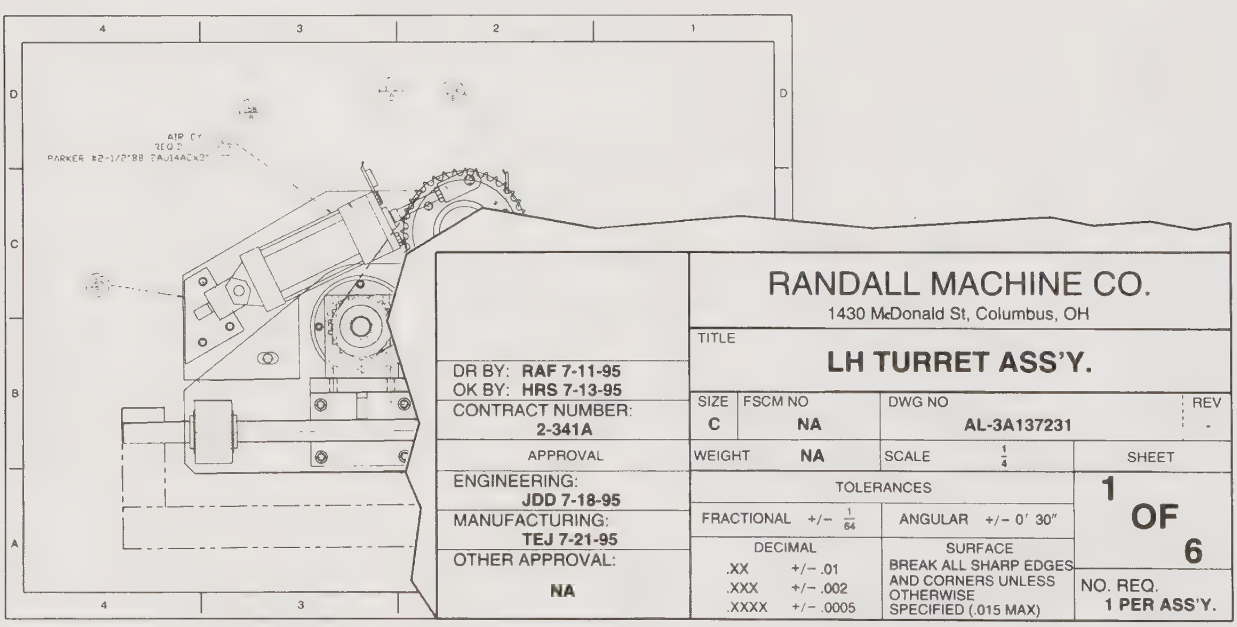
________ 11. The drawing number of the print is ________.

________ 12. The contract number for the job is ________.

________ 13. Angular tolerances are given as ________.

________ 14. The drawing was completed on ________-95.

________ 15. The number of parts required is ________.



LH TURRET ASS'Y.

chapter 2

OBJECT REPRESENTATION

Sketches are used in industry to quickly convey ideas. Sketches may be drawn as pictorial drawings or multiview drawings. Object representation for prints is based on the principles of orthographic projection. The types of lines used and the representation of surface features on multiview drawings are based on standards developed by ANSI. Drawings are dimensioned to show size and location.

SKETCHING

Sketching is drawing without instruments. Sketches are made by the freehand method. The only tools required are a pencil, paper, and an eraser. See Figure 2-1.

Sketching pencils are either wooden or mechanical. Wooden pencils must be sharpened, and the lead must be pointed. Erasers are not commonly placed on sketching pencils.

One type of mechanical pencil contains a thick lead that is pointed with a file, sandpaper, or lead pointer. Another type contains a thin lead which does not require pointing. Softer leads, such as HB, F, and H, are commonly used for sketching.

The paper selected for sketching depends upon the end use of the sketch. Plain paper is commonly used. Tracing vellum is used if the sketch is to be

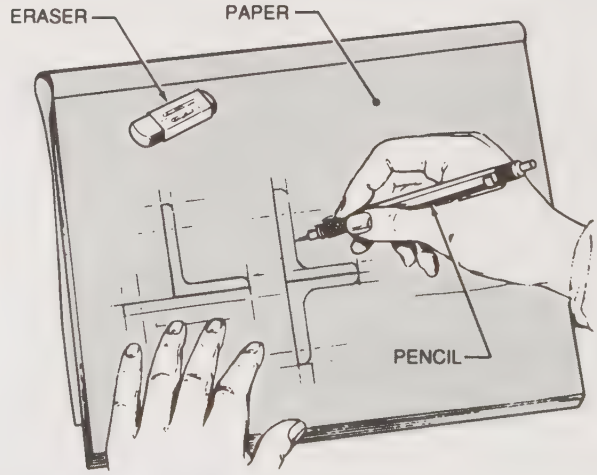


Figure 2-1. Sketching is drawing without instruments.

duplicated on a diazo printer. Sketching papers and tracing vellums are available in pads or sheets in standard sizes designated A, B, or C. Size A is $8\frac{1}{2}'' \times 11''$. Size B is $11'' \times 17''$. Size C is $17'' \times 22''$.

The paper is either plain or preprinted with grids to facilitate sketching. Preprinted paper is available in a variety of grid sizes for orthographic and pictorial sketches. A grid size of $\frac{1}{4}''$ is popular. Grids are commonly printed in light-blue, non-reproducing inks.

Erasers are designed for use with specific papers and leads. The eraser selected should be soft enough to remove pencil lines without smearing lines or damaging the paper. Pink pearl and white vinyl erasers are commonly used while sketching.

Electric erasers and battery-powered erasers are available. These lightweight erasers provide smooth, easy operation with efficient cleanup.

Sketching Techniques

The pencil point should be pulled across the paper while sketching. Pushing the pencil point can tear the paper. While pulling the pencil, slowly rotate it to produce lines of consistent width.

Shading techniques are not used with orthographic drawings. Pictorial drawings may be shaded. Horizontal, inclined, vertical, and curved lines are drawn to produce orthographic and pictorial drawings. See Figure 2-2.

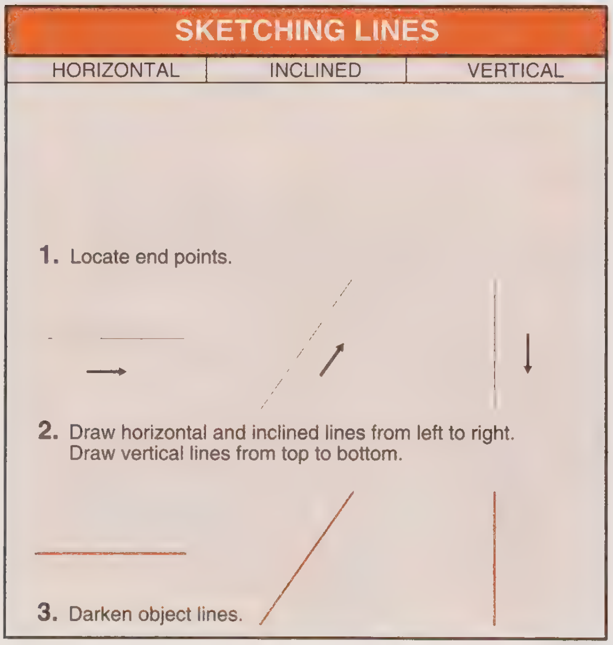


Figure 2-2. Lines are sketched by locating their end points.

Sketching Horizontal Lines. To sketch horizontal lines, locate the end points with dots to indicate the position and length of the line. For short lines, the end dots are connected with a smooth wrist movement from left to right (for a right-handed person). Long lines may require intermediate dots. If grid paper is used, intermediate dots are not required. For long lines, a full arm movement may be required to avoid making an arc.

The top or bottom edges of the paper or pad may be used as a guide while sketching horizontal lines. Light, trial lines are drawn first to establish the straightness of the line. The line is then darkened. With sketching experience, the trial lines may be omitted.

Sketching Vertical and Slanted Lines. To sketch vertical lines, locate the end dots and draw from the top to the bottom. The side edges of the paper or pad may be used as a guide while sketching vertical lines.

Slanted lines are inclined lines. They are neither horizontal nor vertical. To draw slanted lines, locate end dots and draw from left to right (for a right-handed person). The paper may be rotated so that the slanted lines are in either a horizontal or vertical position to facilitate sketching.

Sketching Plane Figures. Pictorial and orthographic drawings consist of lines, arcs and irregular curves, and plane figures in varying combinations. Common plane figures include circles, triangles, quadrilaterals, and polygons. See Figure 2-3.

To sketch circles, locate the centerpoint and draw several intersecting diameter lines. Mark off the radius on these lines, and connect with a series of arcs. The diameter is commonly dimensioned.

To sketch triangles, draw the base, determine the angles of the sides, and draw straight lines to complete. Generally, one or more of the sides is dimensioned and the angle is noted.

To sketch quadrilaterals, draw the base line and determine corner points. Connect the corner points with straight lines to complete. Dimensions of two sides and angles, as required, are often included.

To sketch polygons, locate the centerpoint, and draw a circle of the appropriate size. Mark off the length of each side on the circumference of the circle, and connect with a series of straight lines. Darken the lines to complete the polygon.

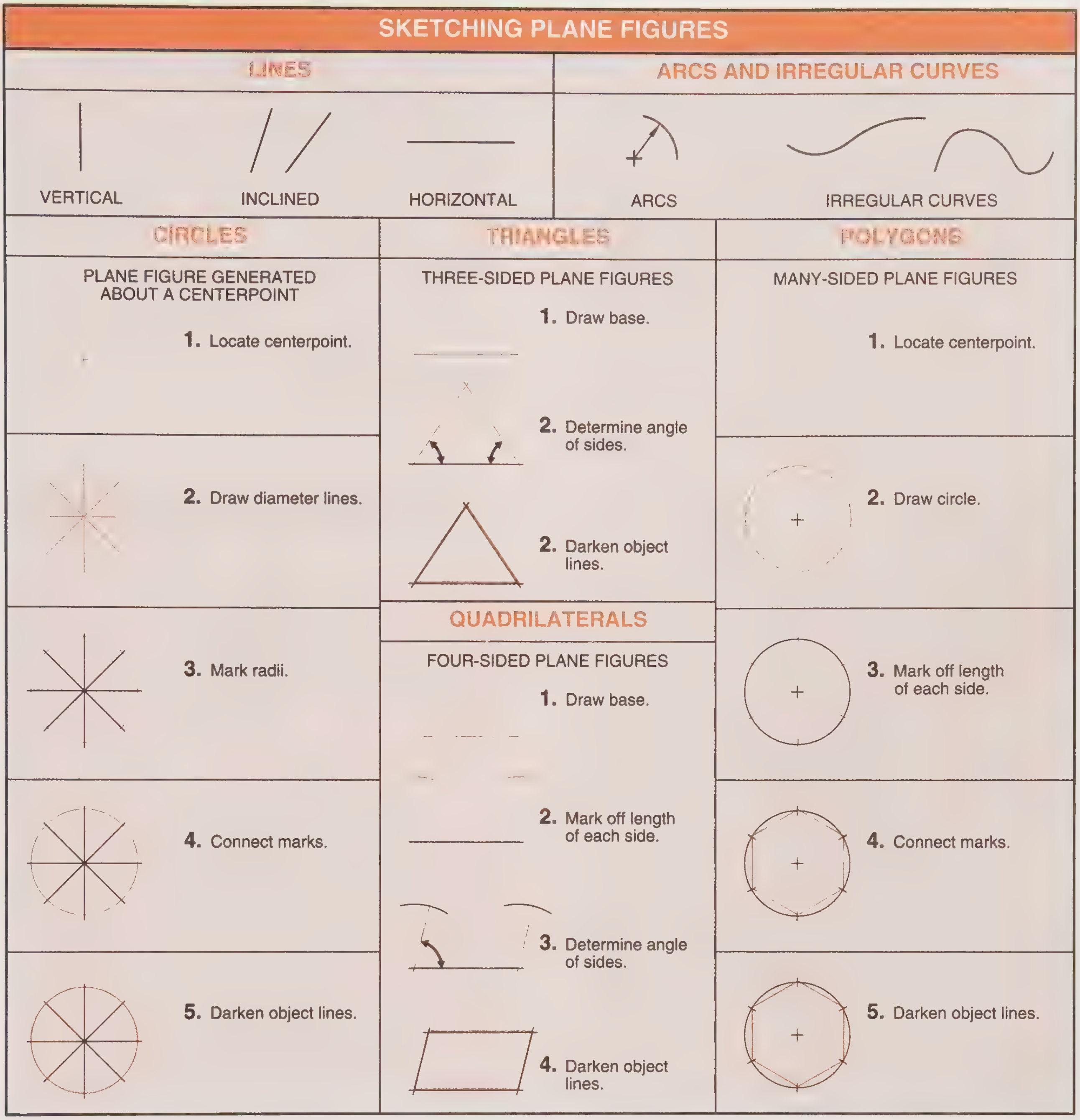


Figure 2-3. Sketches consist of lines, arcs, and plane figures in varying combinations.

PICTORIALS

Pictorial sketches or drawings look like a "picture" because they convey a sense of perspective and realism of the object being viewed. Height, length, and depth of the object are easily shown with various types of pictorial drawings.

While pictorial drawings are only occasionally used when preparing prints, an understanding of their basic concepts aids in the interpretation of prints. Additionally, the ability to quickly sketch a pictorial drawing of an object or detail aids in conveying technical information to others. Three basic types of pictorial drawings are axonometric, oblique, and perspective. Perspective drawings are seldom used on machine trades prints. See Figure 2-4.

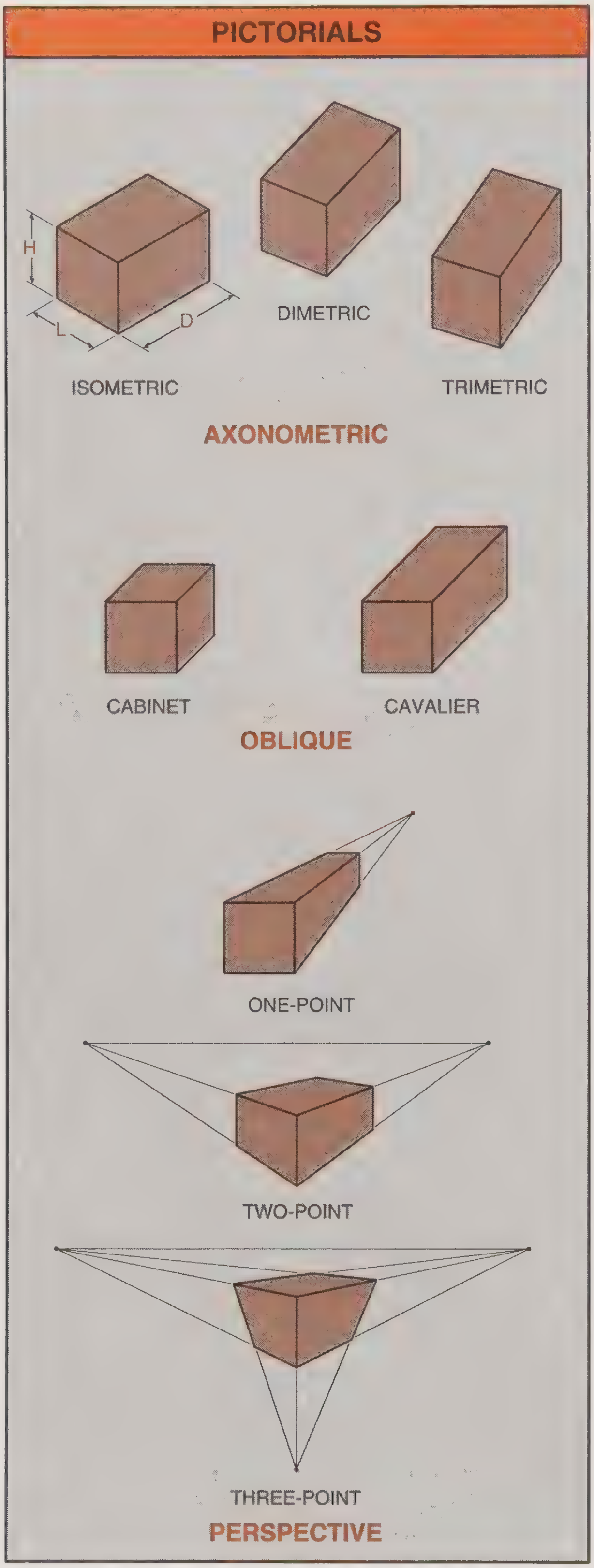


Figure 2-4. Three basic types of pictorial drawings are axonometric, oblique, and perspective.

Axonometric

An *axonometric* drawing is a pictorial drawing showing three sides of an object with horizontal and vertical dimensions drawn to scale and containing no true view of any side. The three basic types of axonometric drawings are isometric, dimetric, and trimetric. Of these, the isometric is the most commonly used. An *isometric* is an axonometric drawing with the axes drawn 120° apart. A *dimetric* is an axonometric drawing with two axes drawn on equal angles and one axis containing either fewer or more degrees. A *trimetric* is an axonometric drawing with all axes drawn at different angles. See Figure 2-5.

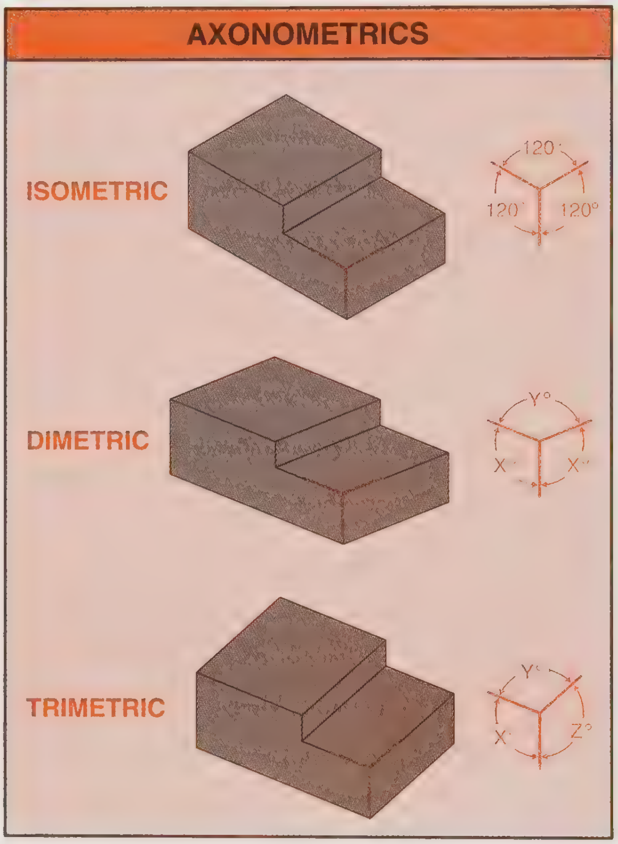


Figure 2-5. Isometrics are the most commonly drawn axonometric drawing.

Isometric. Isometric drawings contain three equal axes that are drawn 120° apart. Because of this 120° angle, no surface appears as a true view; however, the object has a natural appearance because three sides are seen. A *true view* is a view in which the line of sight is perpendicular to the surface.

Because of the skewed sides, circles (drilled holes, counterbores, etc.) appear as ellipses on isometric surfaces. Additionally, arcs appear as portions of ellipses. All surfaces not in one of the three principal isometric planes must be drawn by locating end points of the skewed surface. The end points are connected to complete the skewed surface. See Figure 2-6.

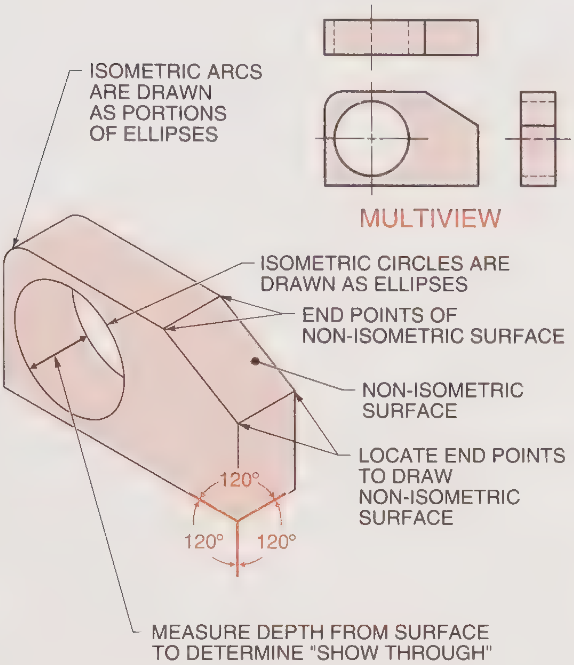


Figure 2-6. Isometrics contain three equal axes drawn 120° apart.

Sketching Isometrics. Isometric sketches are made by the following procedure. See Figure 2-7.

1. Locate the isometric axes and block in the front view using length and height measurements from the multiview. There are two front surfaces on this particular object. These two surfaces are parallel to one another. The depth dimension used to establish the location of the second front surface is taken from either the top or right side view of the multiview.
2. Sketch the outline shape of the front surfaces. Measurements are taken from the multiview. Notice that the arc on the second front surface is drawn as a portion of an ellipse.
3. Locate the centerpoint of the drilled hole on the second front surface. Construct an ellipse using measurements from the front view of the multiview.
4. Draw receding lines long enough to mark the depth of the object. Receding lines are parallel to the isometric axis.
5. Draw lines to establish the back surface. These lines are parallel to the isometric axis.
6. The skewed line on the back surface representing the V portion is drawn to its corresponding line in the front surface. Find the depth through the drilled hole to determine if the back portion of the drilled hole will show through on the front view. Draw a portion of the ellipse as required.
7. Darken all object lines to complete the isometric sketch.

Circles on Isometrics. Circles on isometric surfaces are drawn as ellipses. An *ellipse* is a plane curve with two focal points. The sum of the distances from these two focal points to any point on the ellipse determines the shape of the ellipse. As the distance between the focal points decreases, the ellipse becomes more circular in shape.

For sketching, the parallelogram method of constructing ellipses is often used. In this method, dimensions from the multiview are used to determine the size of the parallelogram. Arcs are then drawn or sketched using the intersecting points as centerpoints. See Figure 2-8.

Oblique

Oblique drawings are pictorial drawings that show one surface of an object as a true view. All other surfaces of the object are distorted by the angle of the receding, oblique lines. All features shown on the face containing the true view are drawn as they appear. Additionally, right angles are shown at 90° on surfaces having a true view. For example, a drilled hole shown on the true view face of an oblique drawing is shown as a circle. Drilled holes on any other surface of the oblique drawing appear as ellipses. The angle at which an ellipse is drawn on these surfaces is determined by the angle of the receding lines. Normally, these lines are drawn on a 30° or 45° angle.

The front view of an object is generally the view which shows the most shape, has the most detail, or is commonly thought of as the front view. The two types of oblique drawings are cabinet and cavalier.

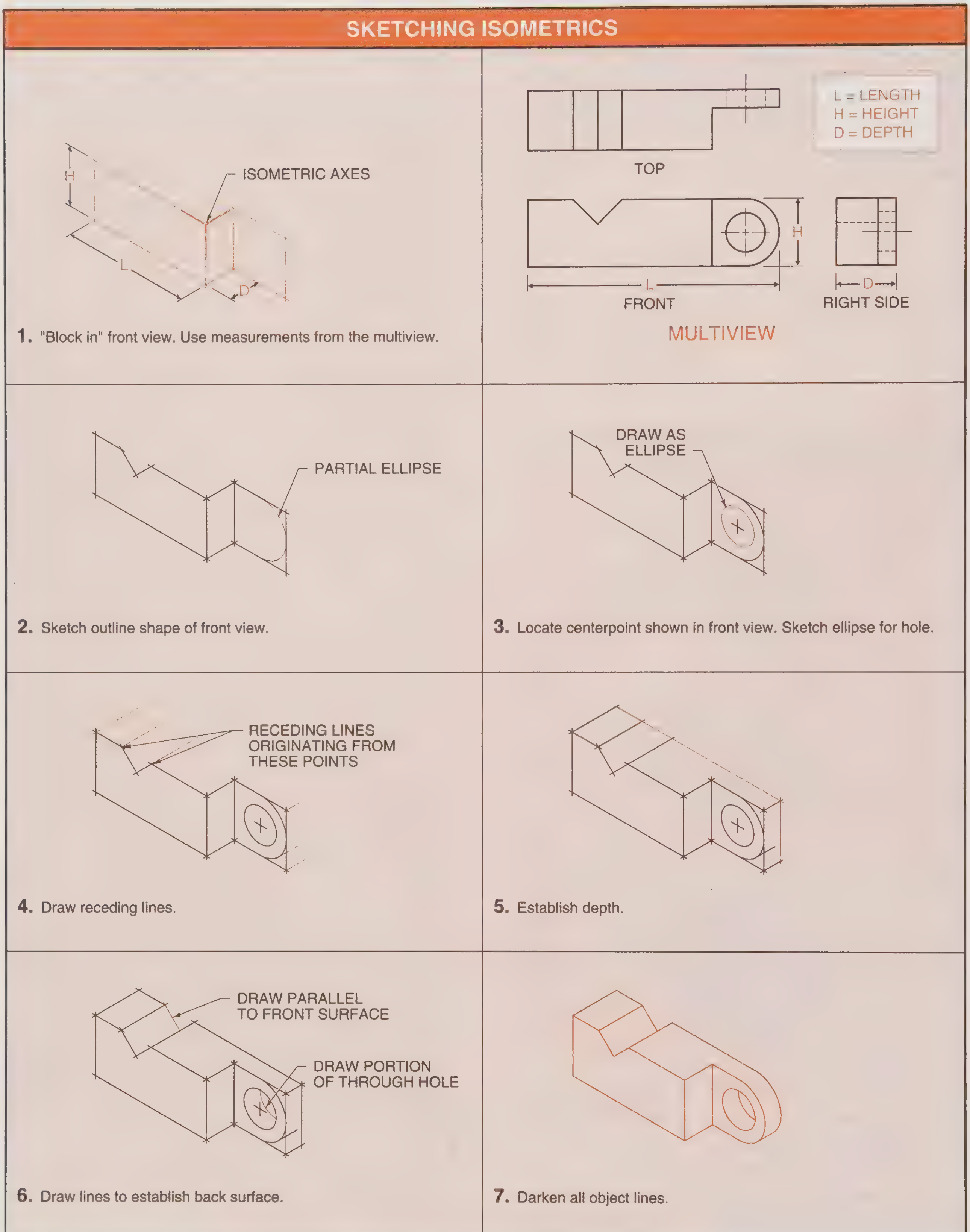


Figure 2-7. Isometrics can be quickly sketched using measurements from the multiview.

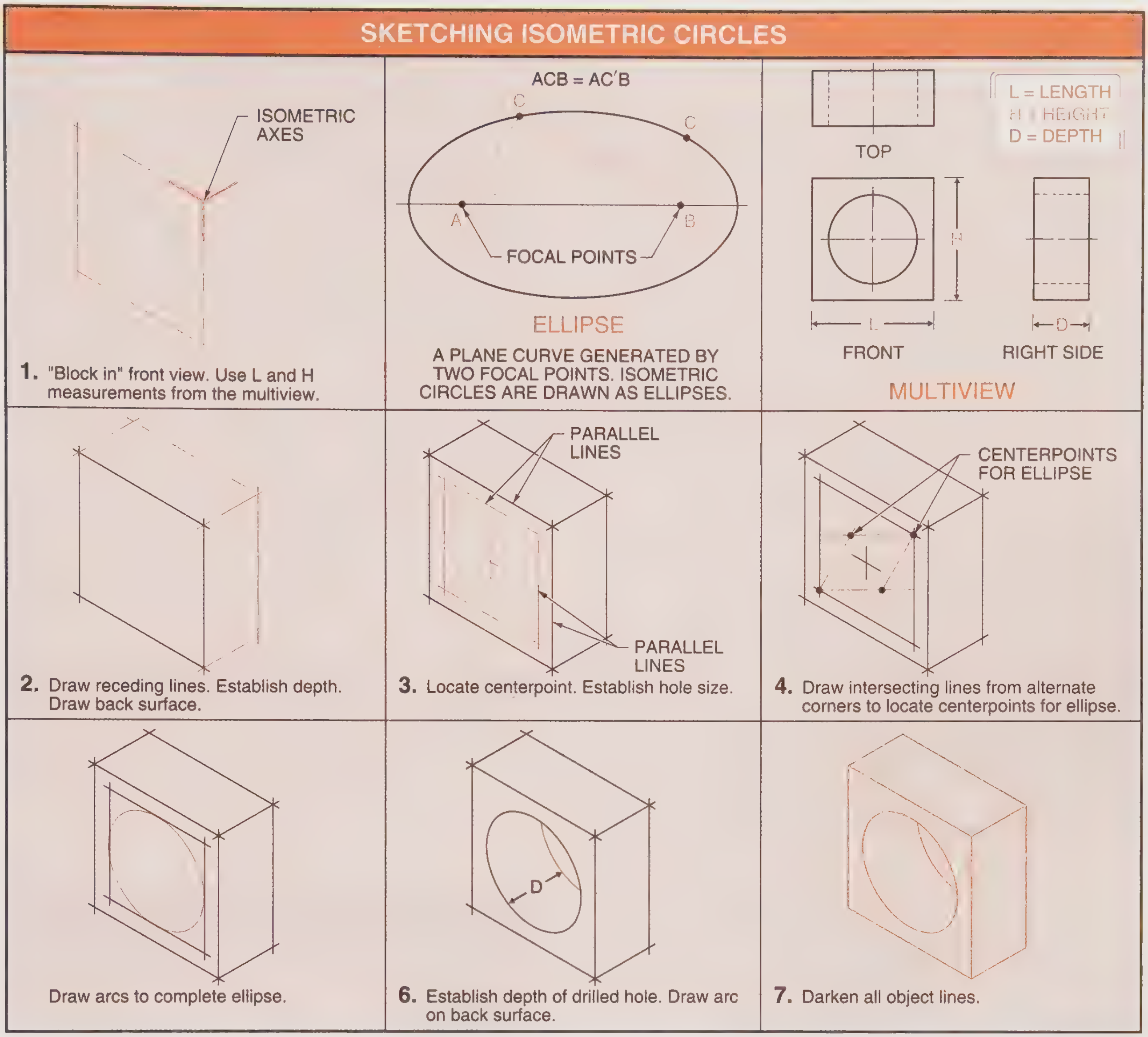


Figure 2-8. Circles on isometrics appear as ellipses.

Cabinet drawings are obliques with receding lines drawn to one-half the scale of lines in the true view. This is the most commonly used type of oblique drawing. *Cavalier* drawings are obliques with receding lines drawn to the same scale as the lines in the true view. The use of the same scale to draw all oblique lines of a cavalier drawing produces a distorted pictorial. Consequently, this type of drawing is seldom used.

Sketching Obliques. Oblique sketches are made by the following procedure. See Figure 2-9.

1. Determine which oblique will be sketched. (An oblique cabinet is shown.)
2. Block in the front view (usually the view with the most detail). Use length and height measurements of the multiview.
3. Complete the outline shape.
4. Locate all centerpoints of circles and arcs. Sketch circles and arcs.
5. Draw receding lines long enough to mark the depth of the object. Receding lines shown are drawn at a 45° angle. They could also be drawn at a 30° angle.
6. Establish depth dimension from the right side or top view of the multiview. Note that only one-half the dimension shown is drawn for the depth of the oblique cabinet.

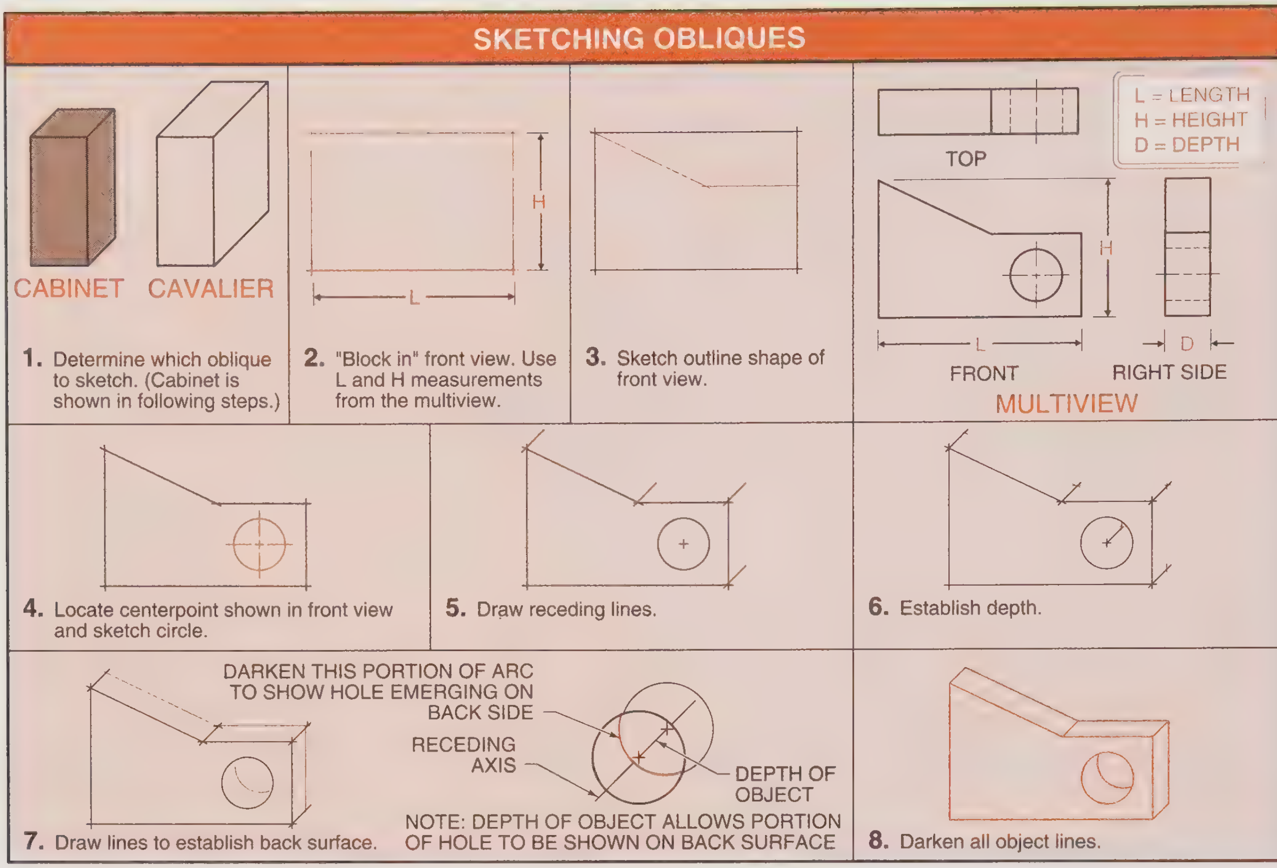


Figure 2-9. Obliques show one surface on an object as a true view.

7. Draw lines to represent the object's back surface. Draw receding lines. Find the depth through the drilled hole to determine if the back portion of the drilled hole will show through on the front view. Draw portion of hole as required.
8. Darken all object lines to complete the oblique sketch.

ORTHOGRAPHICS

Orthographic projection (multiview drawing) is drawing at right angles. In multiview drawing, each view of an object is shown two-dimensionally. The six basic views of a multiview drawing are front, top, right side, back, left side, and bottom. The front, top, and right side are the most common views. Each view has a definite relationship of position with each other view. These views are projected from one another. See Figure 2-10.

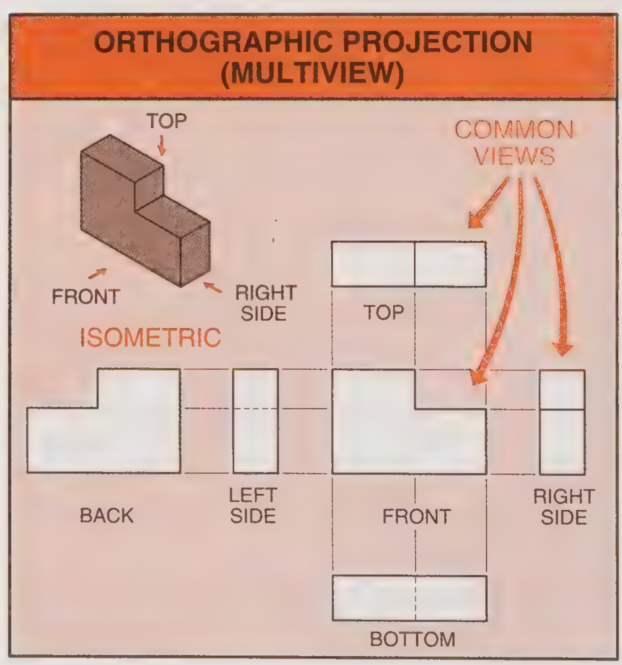


Figure 2-10. The front, top, and right side of a multiview are the most common views.

Multiviews

Machine trades prints use multiview (orthographic) drawings to show the various views of the object. Multiview drawings are based on the principle of showing each view of an object in detail. All objects have three basic dimensions: length, height, and depth. Any one view of a multiview drawing can only show two of these dimensions. For example, the front view shows length and height; the top view shows length and depth; and the right side view shows height and depth.

Only two views of any object are required to show the three basic dimensions. For example, two views of a cylindrical object show the three basic dimensions of length, height, and depth. The front view shows length and height, and the top view shows length and depth (which is the diameter of the cylindrical object). For most multiview drawings, however, the front, top, and right side views are required to clearly show all details. See Figure 2-11.

VIEW	SHOWS
Front	Length and height
Top	Length and depth
Right Side	Height and depth

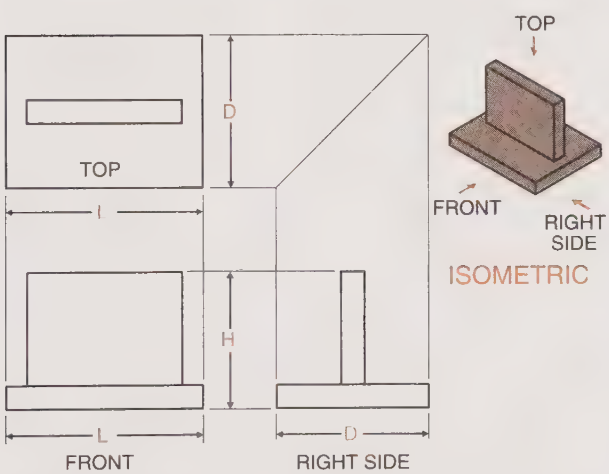


Figure 2-11. Any one view of a multiview shows two dimensions.

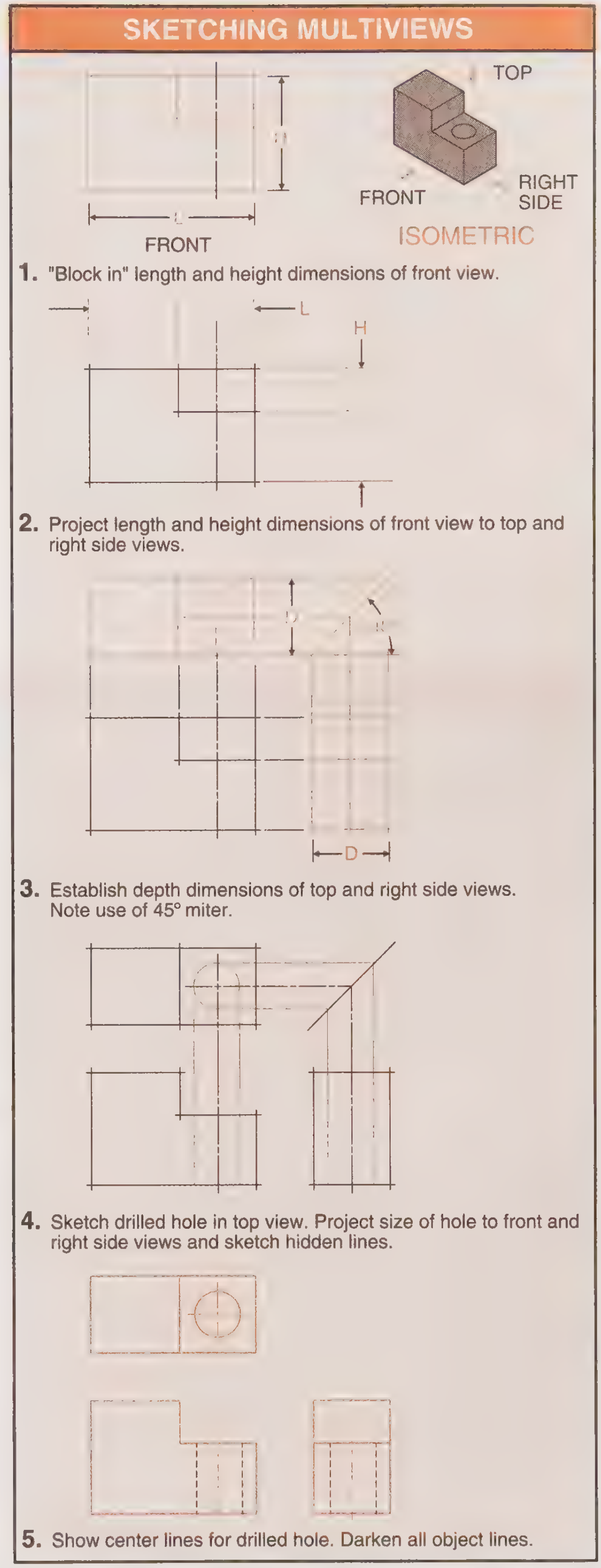


Figure 2-12. Dimensions of views in a multiview are projected from adjacent views.

Sketching Multiviews. Multiview sketches are made by the following procedure. See Figure 2-12.

1. Block in the length and height dimensions of the front view. Locate the front view to allow even spacing of views.

2. Project the length and height dimensions of the front view to the top and right side views.
3. Establish depth dimensions of the top and right side views. The depth dimension is shown with a 45° miter line on the right side of the top view to establish the same depth dimension in the right side view.
4. Sketch the drilled hole in the top view. Project hole dimensions to the front and right side views and draw hidden lines.
5. Draw center lines. Darken all object lines to complete the multiview sketch.

Dimensions

Dimensions are numerical values that give size, form, or location of objects. All dimensions required to fabricate the part should be given. Dimensions are placed according to the function and mating relationship of a part. They should be placed so that they allow only one interpretation.

Drawings do not commonly specify manufacturing methods. The manufacturing method is commonly determined by the engineering department.

Linear dimensions are dimensions that measure lines and are commonly expressed as decimal inches or millimeters. See Appendix. The decimal inch is predominately used in the United States. Decimal dimensions on prints are commonly expressed in hundredths of an inch (.01″), thousandths of an inch (.001″), and ten thousandths of an inch (.0001″).

Angular dimensions are dimensions that measure angles and are commonly expressed as degrees and decimal parts of a degree, or as degrees, minutes, and seconds. If the same dimensioning system is used throughout a drawing, inch marks (″) or millimeter (mm) designations may be omitted. A general note on the print, however, should specify the dimensioning system used. See Figure 2-13.

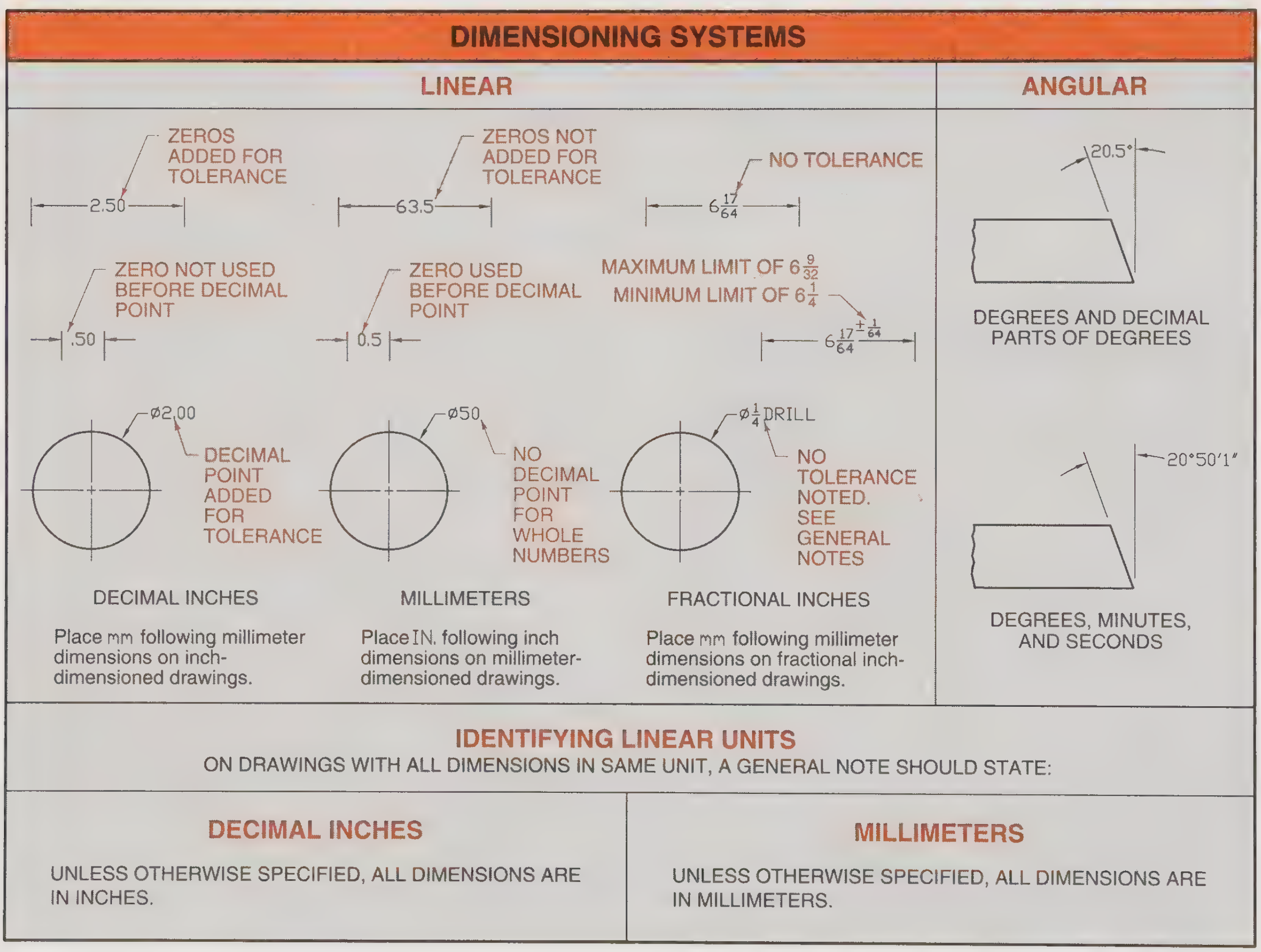


Figure 2-13. Dimensions are linear or angular.

Fractional dimensions are dimensions that measure lines and are commonly expressed as inches and fractional parts of an inch. They are generally used on ordinary work not requiring a high degree of tolerance. *Tolerance* is the amount of variation allowed above or below a dimension. For example, a part with a specified dimension of $4\frac{1}{8}'' \pm \frac{1}{64}''$ is acceptable anywhere between $4\frac{7}{64}''$ ($4\frac{1}{8}'' - \frac{1}{64}'' = 4\frac{7}{64}''$) and $4\frac{9}{64}''$ ($4\frac{1}{8}'' + \frac{1}{64}'' = 4\frac{9}{64}''$).

Fractional dimensions are commonly based on fractional sizes having a denominator that is a multiple of 4. For example, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, and $\frac{1}{64}$ are the common denominators used with fractional parts of an inch.

Dimensions and notes are placed to read from the bottom of the sheet. They are generally placed outside the view of the object. See Figure 2-14.

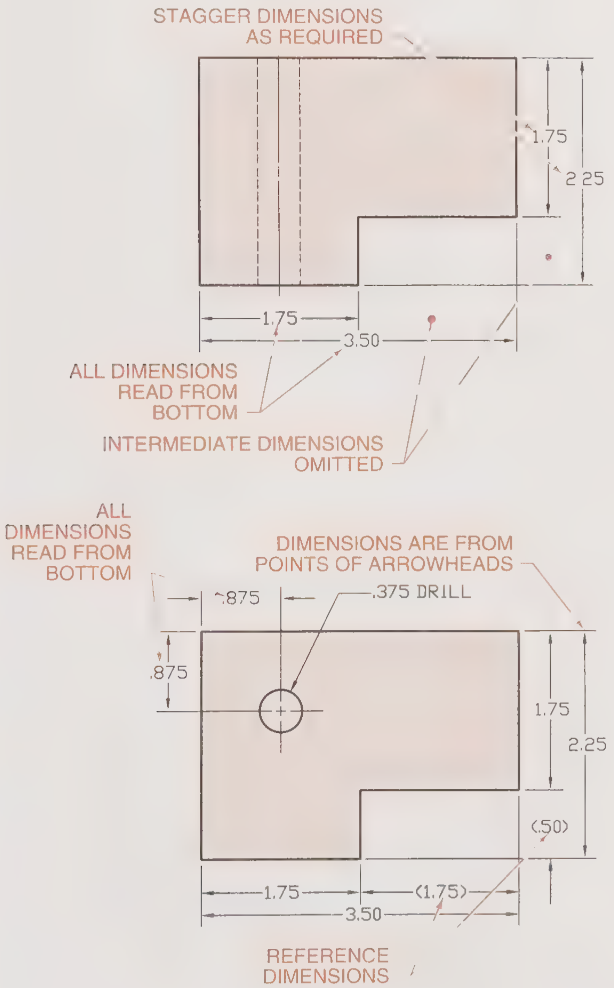


Figure 2-14. Dimensions and notes read from the bottom of the sheet.

Intermediate dimensions are placed nearest the object, and the overall dimension is placed farthest from the object. One intermediate dimension is omitted, or indicated as a reference dimension, if an overall dimension is used. A reference dimension is indicated by the placement of parenthetical brackets around the dimension.

Lines

All drawings are composed of lines to show the shape of the drawn object. Lines may be drawn by the conventional method or by CAD. CAD lines are in linetype libraries. A *linetype library* is a CAD file that contains dashed, hidden, center, phantom, dot, dotdash, border, and divide lines.

Lines on prints have specific meanings. They are drawn based on conventions recommended by "Line Conventions and Lettering" (ANSI Y14.2M).

All lines should be sharp and dark. Lines are either thick or thin. Thick lines should be approximately .032″ (0.7 mm) wide. Thin lines should be approximately .016″ (0.35 mm) wide.

Common lines on drawings include object, hidden, center, dimension, extension, leader, cutting plane, section, and break lines. Each of these lines has a unique appearance that allows it to be easily recognized.

Dimension lines, extension lines, and leaders are used in conjunction with numerals to apply dimensions to the object. Dimensions are specified by "Dimensioning and Tolerance" (ANSI Y14.5M). See Figure 2-15.

Object Lines. *Object lines* are lines that define the visible shape of an object. They are used wherever there is a distinct change in the surface. Object lines are thick and dark. They are the most common lines shown on a print.

Hidden Lines. *Hidden lines* are lines that represent shapes which cannot be seen. Hidden lines are used wherever there is a distinct change in the surface. Hidden lines are thin and dark. They are drawn with a series of $\frac{1}{8}''$ (3 mm) dashes separated by $\frac{1}{32}''$ (0.75 mm) spaces.

Views to be drawn should be selected to minimize the use of hidden lines. A large number of hidden lines in one view makes the view difficult to read.

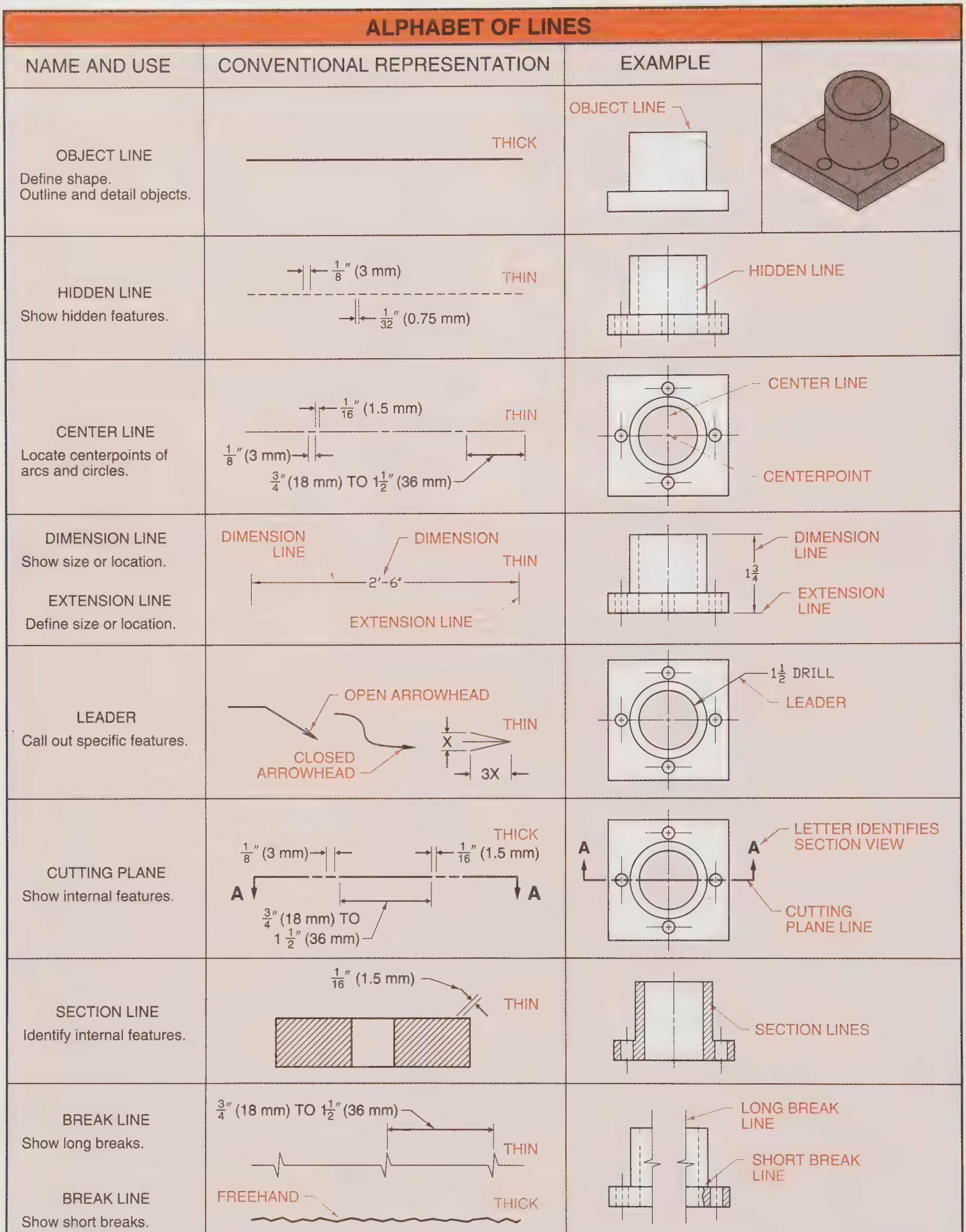


Figure 2-15. Lines on prints have specific meanings.

Center Lines. *Center lines* are lines that locate the centerpoints of arcs and circles. Center lines are thin and dark. They are drawn as a series of long and short dashes separated by spaces. The long dashes are from 3/4″ (19 mm) to 1 1/2″ (38 mm) long. The short dashes are 1/8″ (3 mm) long. The spaces are 1/16″ (1.5 mm) long.

Centerpoints for arcs and circles are represented by two short dashes crossing one another at right angles. Centerpoints are drawn in the centers of all circles and arcs.

Dimension Lines. *Dimension lines* are lines that are used with dimensions to show size or location. They are thin and dark. Dimension lines are commonly broken for the placement of numerals giving the measurement. If a horizontal dimension line is not broken, the numeral is placed above the dimension line. See Figure 2-16.

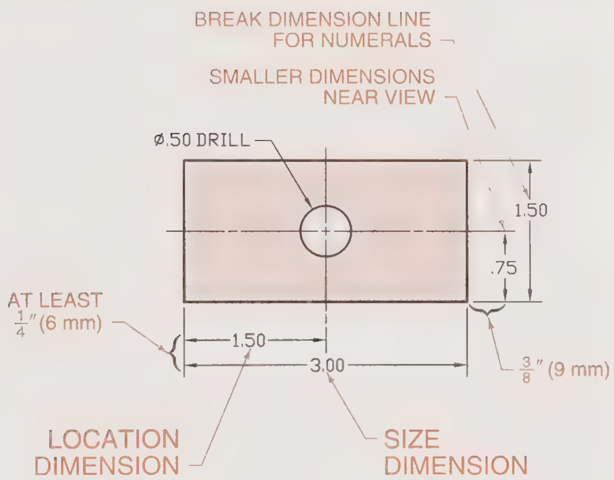


Figure 2-16. Dimension lines show size or location.

Dimension lines are terminated by arrowheads. An *arrowhead* is a symbol that indicates the extent of a dimension. Arrowheads are approximately 1/8″ (3 mm) long and are three times as long as they are wide. Arrowheads may be open or closed. See Figure 2-17.

Smaller dimensions are placed near the view. Intermediate dimensions are placed outside of smaller dimensions. Overall dimensions are placed the farthest from the view. The dimension line nearest the view should be at least 3/8″ (9 mm) from the view. Succeeding dimension lines should be no closer than 1/4″ (6 mm).

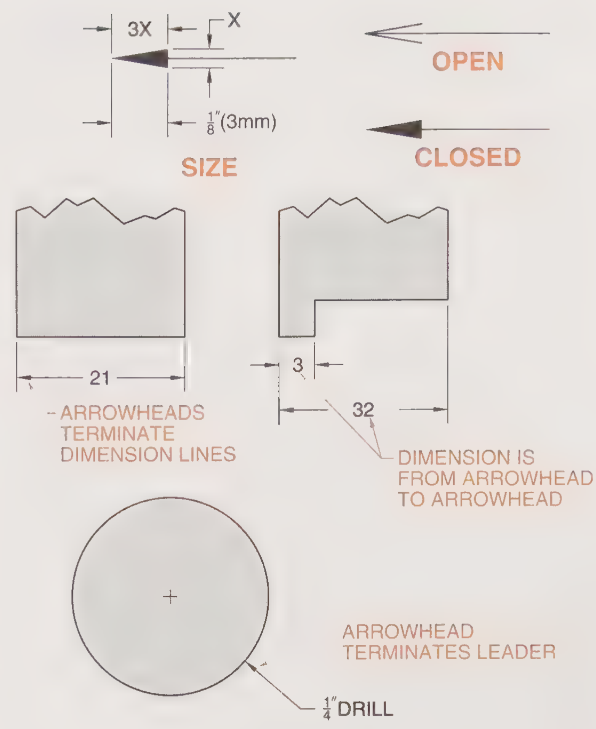


Figure 2-17. Dimension lines and leaders are terminated by arrowheads.

For parallel dimension lines, the dimensions are staggered to avoid crowding. Dimensions are aligned for appearance. Dimension lines should not cross other dimension lines.

Extension Lines. *Extension lines* are lines that extend from surface features and terminate dimension lines. They are thin and dark. Extension lines should not touch the feature from which they are extended. A 1/16″ (1.5 mm) gap separates the extension line from the part.

Generally, extension lines should not cross other extension lines or dimension lines. If they must cross, they are not broken. If extension lines must cross arrowheads, they are broken. Extension lines extend 1/8″ (3 mm) beyond the dimension line. See Figure 2-18.

Leaders. *Leaders* are lines that connect a dimension, note, or specification with a particular feature of the drawn object. They call out specific features such as drills, countersinks, counterdrills, etc. They are thin and dark.

One end of a leader terminates with an arrowhead or a dot. Arrowheads terminate on a line. Dots are placed within an area. The other end of the leader

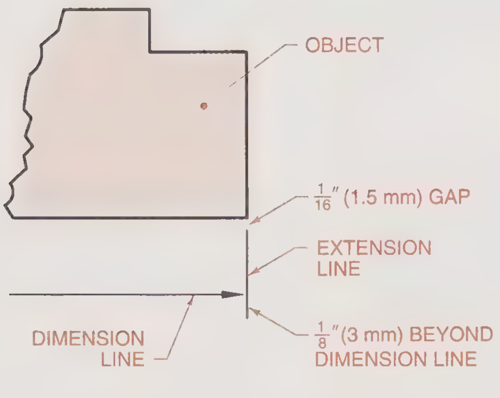


Figure 2-18. Extension lines terminate dimension lines.

is generally connected to a shoulder although this is optional. The ¼″ (6 mm) shoulder is centered on the lettering at the beginning or ending of the dimension, note, or specification.

Leaders are inclined (slanted) lines. Leaders are commonly not drawn in a horizontal or vertical position. They are drawn at an angle so they will show up easily. See Figure 2-19.

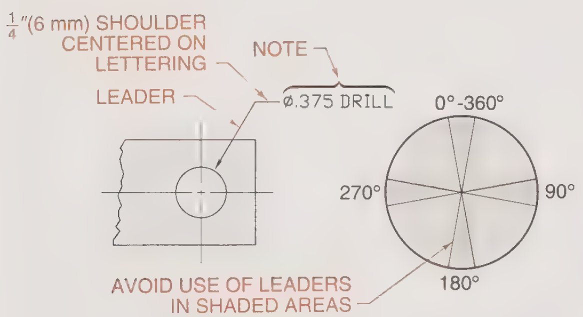


Figure 2-19. Leaders connect notes with a particular feature of the drawn object.

Cutting Plane Lines. *Cutting plane lines* are lines that show where an object is imagined to be cut in order to view internal features. They are thick and dark. Cutting plane lines are drawn as a series of long single and short double dashes. Long single dashes are from ¾″ (19 mm) to 1½″ (38 mm) long. Short double dashes are ⅛″ (3 mm) long. Spaces are ¹⁄₁₆″ (1.5 mm) long.

Arrowheads on the ends of the cutting plane line indicate the direction of sight. Letters near the arrowheads identify the section view.

Section Lines. *Section lines* are lines that identify the internal features cut by a cutting plane line. They are thin and dark. Section lines are drawn at an angle and are spaced 1/16″ (1.5 mm) apart for general section lines. Specific configurations of section lines identify the particular type of material.

Break Lines. *Break lines* are lines that can show internal features or avoid showing continuous features. Long break lines are drawn with a thin, dark line containing a zig-zag every ¾″ (19 mm) to 1½″ (38 mm). Short break lines are drawn with a thick, dark, freehand line.

SURFACE FEATURES

Metal may be cast or forged, and then machined as required. *Cast* metal parts are made by heating metal to its liquid state and pouring it into a mold where it cools and resolidifies. *Forged* metal parts are made by forming metal by a mechanical or hydraulic press with or without heat.

The surface of a metal part may be rough or finished. A rough surface appears as cast or forged. A finished surface is machined. Finished surfaces are required where parts mate or fit together. Surfaces, holes, fillets and rounds, and runouts produce surface features.

Surface features are any part of the surface where change occurs. A *normal surface* is a plane surface parallel to a plane of projection. It appears as a true view in the orthographic view to which it is parallel. It appears as a vertical or horizontal line on the remaining two orthographic views. An *oblique surface* is a plane surface not parallel to any plane of projection. It does not appear as a true view in any orthographic view. An oblique surface appears foreshortened in all orthographic views.

An *inclined surface* is a plane surface perpendicular to one plane of projection and inclined to the remaining two orthographic views. *Intersecting surfaces* are created when one surface meets another surface. Distinct changes in surfaces are represented by object lines. Smooth changes in surfaces, such as when a curved surface becomes tangent to a flat surface, are not represented by object lines. See Figure 2-20.

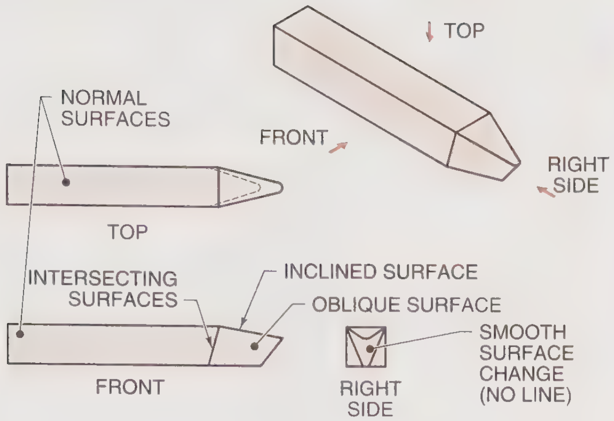


Figure 2-20. Surfaces are defined by lines.

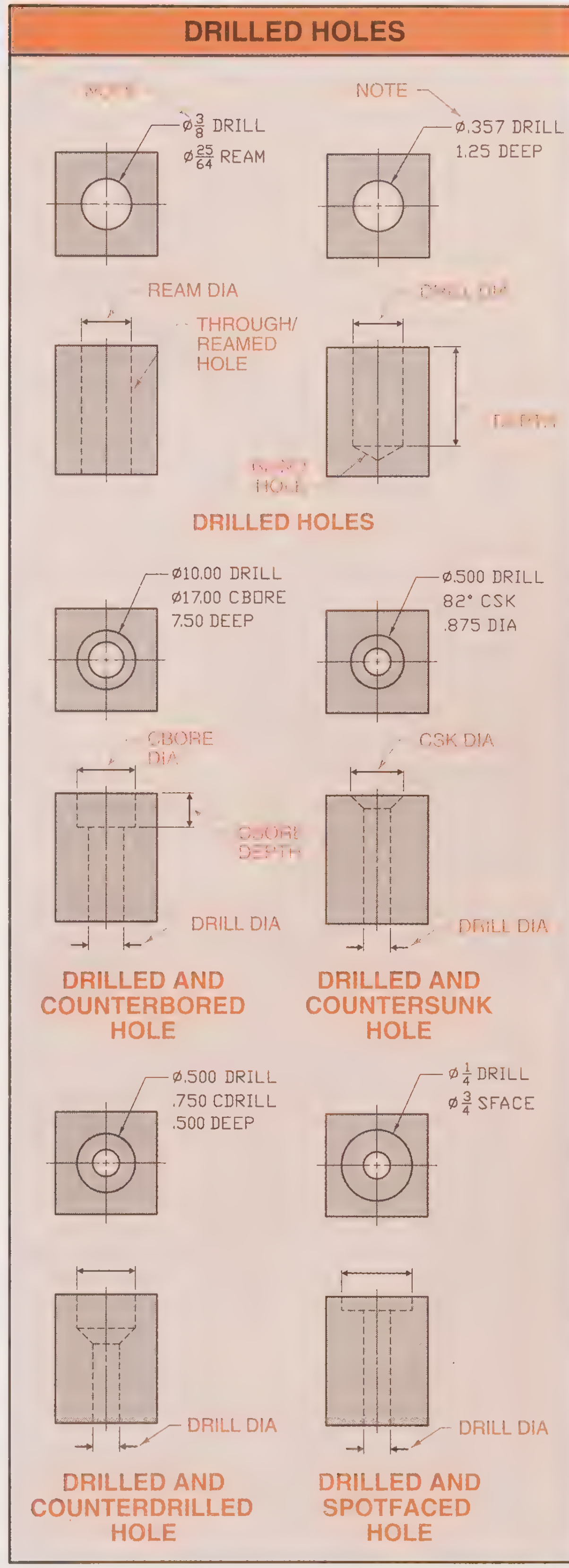


Figure 2-21. Hole sizes are specified by diameters.

Holes

Holes appear as circles in one view and in profile in adjacent views. Hole sizes are specified by their diameters. They are never specified by their radii. Notes give the size and type of hole. For example, a typical note that reads ∅ .750 DRILL-2.50 DEEP indicates that the diameter of the drill used to drill the hole is 3/4″ and the hole is to be drilled 2 1/2″ deep. The diameter of the hole (.750) is given first and is followed by the operation (drill).

A *through hole* is a drilled hole passing completely through the material. A *blind hole* is a drilled hole that does not pass through the material. The depth of blind holes is specified in the notes. The depth is measured only along the cylindrical portion of the drilled hole. The point of the drill leaves a cone shape in the bottom of the drilled hole. This cone shape is generally drawn as a 90° angle although it may be from approximately 80° to approximately 118°. Common operations to produce holes include drilling, reaming, counterboring, countersinking, and spotfacing. See Figure 2-21.

Drilled Holes. A *drill* is a round hole in a material produced by a twist drill. Twist drills (also known as drills) are sized by their diameter. Sizes are designated by numbers 1 through 80, letters A through Z, and fractions from 1/64″ to 3 1/2″. See Appendix. A No. 1 drill has a diameter of .2280″. A No. 80 drill has a diameter of .0135″. An A drill has a diameter of .234″. A Z drill has a diameter of .413″.

Fractional drills from $\frac{1}{64}''$ to $1\frac{3}{4}''$ are available in $\frac{1}{64}''$ increments. From $1\frac{3}{4}''$ to $2\frac{1}{4}''$, they are available in $\frac{1}{32}''$ increments. From $2\frac{1}{4}''$ to $3\frac{1}{2}''$, they are available in $\frac{1}{16}''$ increments.

Drills in metric sizes are also available. See Appendix. A drill appears as a circle in one view and as parallel hidden lines in the adjacent view.

The diameter of the drill is dimensioned in the circular view by the diameter extended to a note containing the dimension, extension lines terminating the diameter which contains the dimension, or a leader from a note containing the dimension. The symbol for diameter is ∅. The ∅ precedes the actual dimension.

The centerpoint is common on all circular views of drilled holes. The center line is common on all side views of drilled holes. The centerpoint and center line represent the axis of the concentric surfaces.

The depth of a drill is measured from the surface to the bottom of the cylindrical hole. The angle at the head of the drill is not included in the depth measurement. If it is not clear that a drill passes completely through the material, the dimension for the drill is followed by the abbreviation THRU. Drilled holes may be counterbored, countersunk, counterdrilled, or spotfaced.

Reaming is enlarging and improving the surface quality of a hole. Standard reamers are available in $\frac{1}{64}''$ (0.375 mm) increments.

Counterbored Holes. A *counterbored hole* is an enlarged and recessed hole with square shoulders. Counterbored holes permit screw heads or other mating parts to be recessed below the surface of the part.

The diameter of the smaller hole is given first. The diameter of the larger (counterbored) hole is given next, followed by the depth of the counterbore, if given. The abbreviation CBORE is commonly used on notes.

Countersunk Holes. A *countersunk hole* is a hole with a cone-shaped opening or recess at the outer surface. Countersunk holes permit the flush seating of parts with angled or tapered heads. For example, a flathead screw can be positioned in a countersunk hole so that the head is flush (level) with the surface. A *countersink* is the tool that produces a countersunk hole. Countersinks are commercially available with standard included angles of 60° or 82°.

Countersunk holes are dimensioned by giving their drill diameter first. The diameter of the countersunk portion is given next, followed by the angle of the countersunk portion. The abbreviation CSK is commonly used on notes.

Counterdrilled Holes. A *counterdrilled hole* is a hole with a cone-shaped opening below the outer surface. Counterdrilled holes permit the recessed seating of parts with angled or tapered heads. For example, a flat head screw can be positioned in a countersunk hole so that the head is recessed below the surface.

Counterdrilled holes are dimensioned by giving their drill diameter first. The diameter of the counterdrilled portion is given next, followed by the depth of the counterdrilled portion. The included angle of the counterdrill is optional. The abbreviation CDRILL is commonly used on notes.

Spotfaces. A *spotface* is a flat surface machined at a right angle to a drilled hole. Spotfaces may be recessed below the surrounding surfaces or may be machined slightly above the surrounding surfaces. They provide an area for tight fits of square-shouldered parts.

Spotfaces are dimensioned by giving their drill diameter first. The diameter of the spotface is given next. The depth of the spotface or the remaining thickness of the material is optional. The abbreviation SF is commonly used on notes.

Edges and Corners

Edges are the intersection of two surfaces. *Corners* are angular spaces at the intersection of surfaces. Dimensions are required to note the sizes of the surfaces and geometric characteristics of the edges and corners. Fillets, rounds, and runouts are examples of corners. Bevels and chamfers are examples of edges.

Fillets and Rounds. A *fillet* is a rounded interior corner. A *round* is a rounded exterior corner. Fillets and rounds are used to avoid sharp corners on objects. A rounded corner is produced by two intersecting rough surfaces. Sharp corners are produced by machining either or both intersecting surfaces. See Figure 2-22.

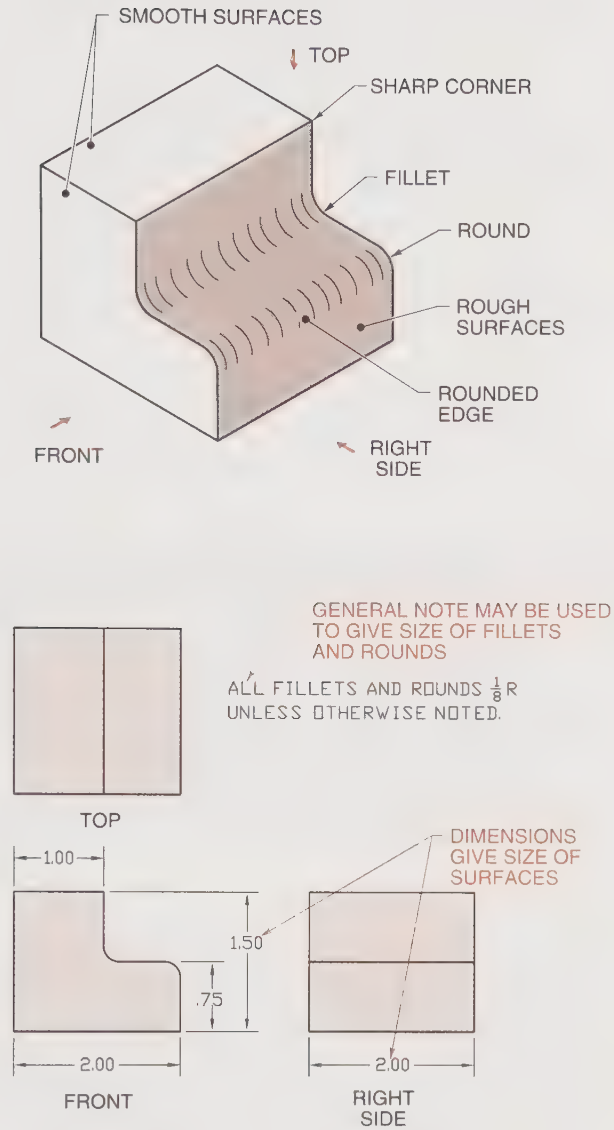


Figure 2-22. Fillets and rounds are used to avoid sharp corners on objects.

Runouts. A *runout* is the curve produced by a plane surface tangent to a cylindrical surface. The radius of a runout is commonly equal to that of a fillet. The direction of the runout is determined by the intersecting surfaces that form the runout. See Figure 2-23.

Bevels. A *bevel* is a sloped edge of an object running from surface to surface. Neither intersection with the surfaces of the object is 90°. A bevel is commonly dimensioned by an angle and a linear dimension. See Figure 2-24.

Chamfers. A *chamfer* is a sloped edge of an object running from surface to side. Chamfers are often used to reduce sharp corners. They are commonly dimensioned by an angle and a linear dimension or by two linear dimensions.

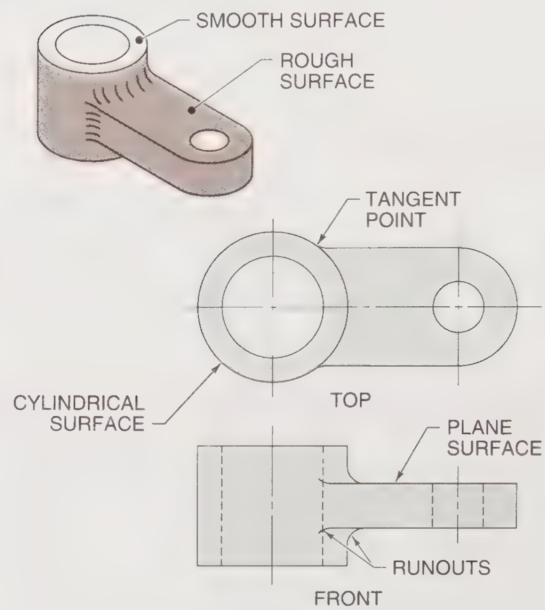


Figure 2-23. Runouts are curves produced by a plane surface tangent to a cylindrical surface.

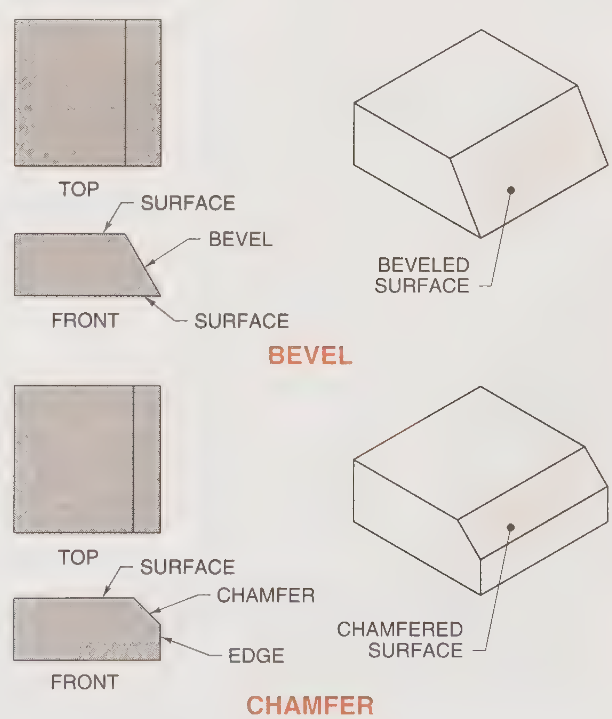


Figure 2-24. A bevel extends from surface to surface. A chamfer extends from surface to edge.

Conventional Breaks

A *conventional break* is a standard method of showing shortened views of elongated objects. Parts drawn with conventional breaks must be uniform in cross-sectional appearance. The drawing is dimensioned as if the complete part is shown. See Figure 2-25.

ABBREVIATIONS AND SYMBOLS

Abbreviations and symbols are used on prints to conserve space, promote consistency, and because they are easily recognizable. An *abbreviation* is a shortened version of the letters forming a word. For example, the abbreviation for centimeter is cm. Because abbreviations are representative of words in a specific language, they vary in different languages.

A *symbol* is a conventional representation of a quantity or unit. Symbols are not based on any specific language and can be easily recognized. For example, the symbol for diameter is ∅. The use of symbols is preferred over the use of abbreviations when an option exists. For example, use the symbol for diameter ∅ instead of the abbreviation (D) when possible.

Always use the symbol for math operations. Never use abbreviations for math operations. For example, do use A = 12; do not use A EQL 12. See Appendix.

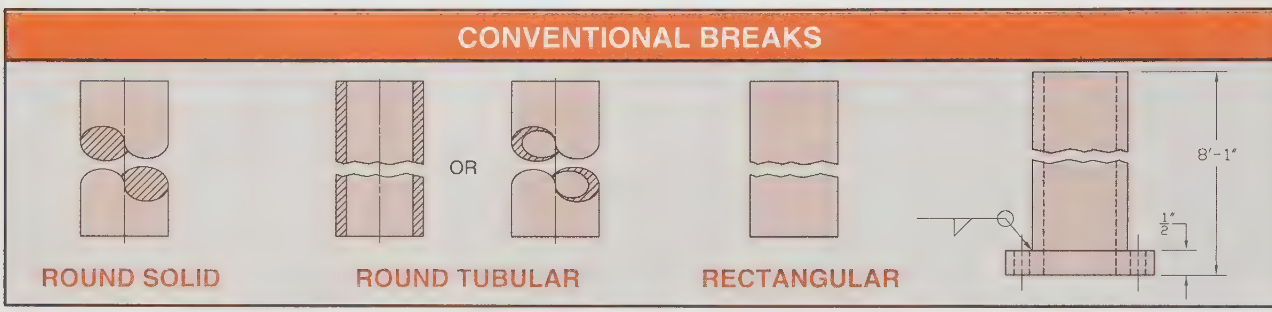
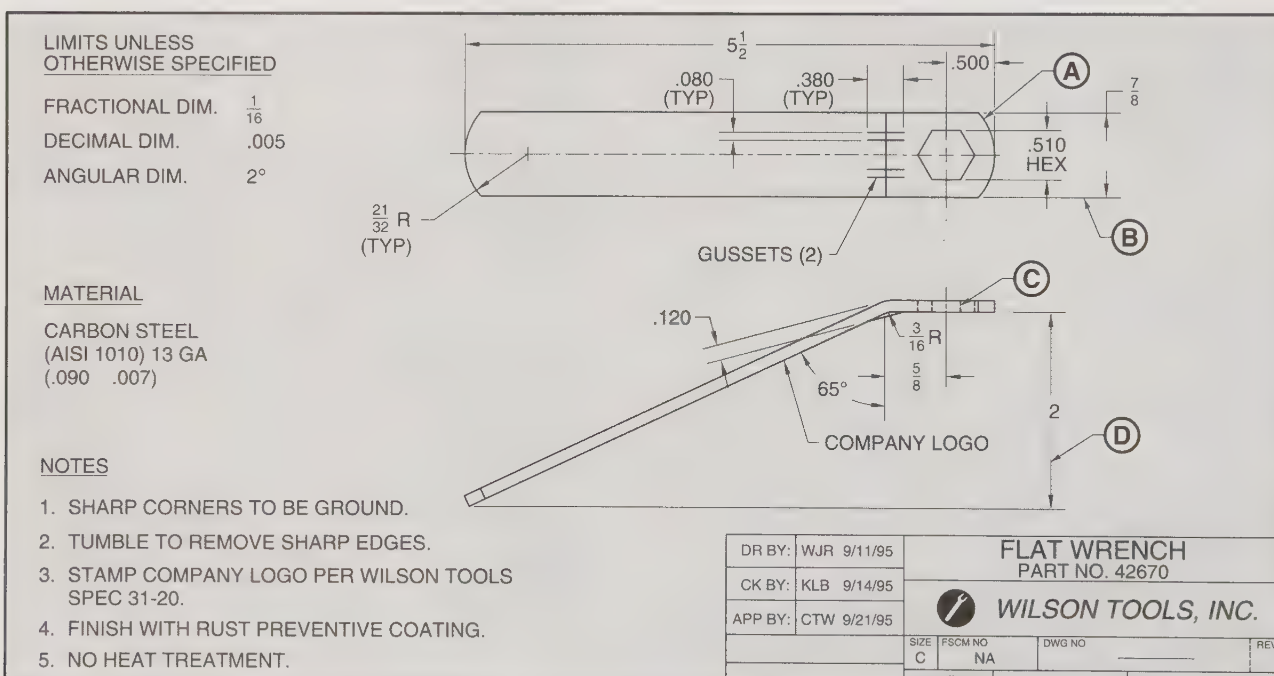


Figure 2-25. Conventional breaks allow details of elongated objects to be shown clearly.



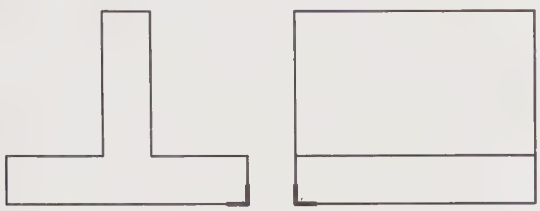
FLAT WRENCH

Name ______________________ Date ______________

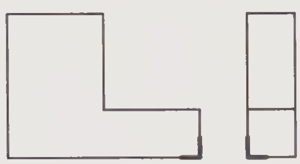
Sketching — Isometrics

Sketch isometrics of the machined parts.

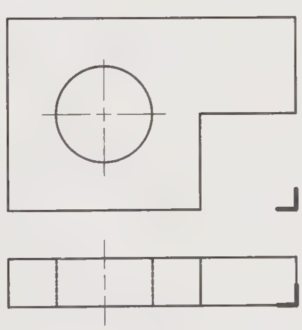
①



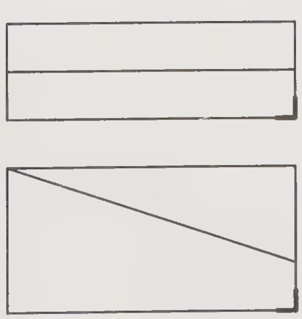
②

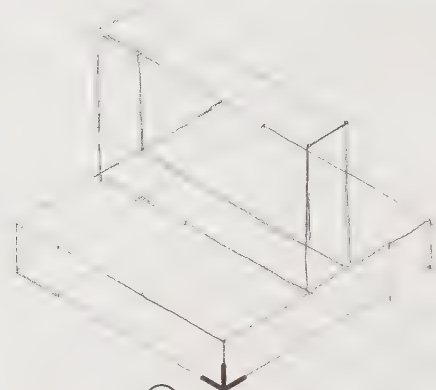


③

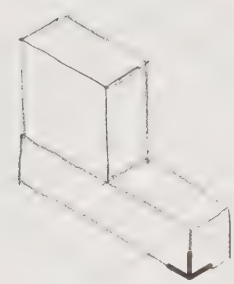


④



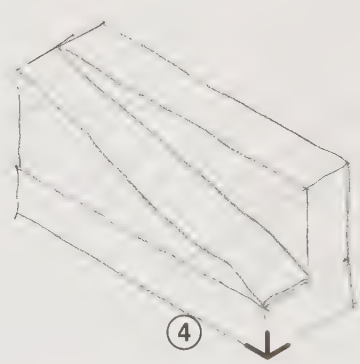


①



②

③

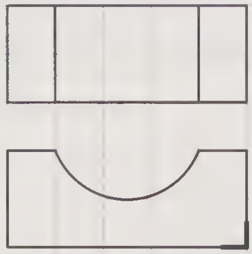


④

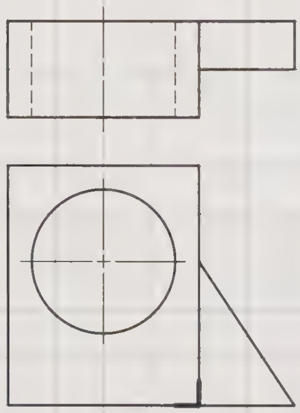
Sketching — Obliques

Sketch oblique cabinets of the multiviews.

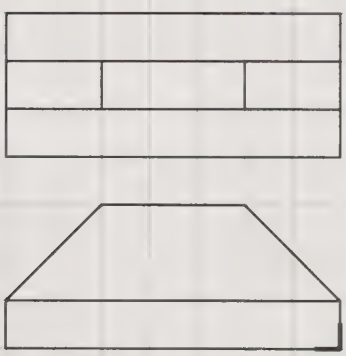
①



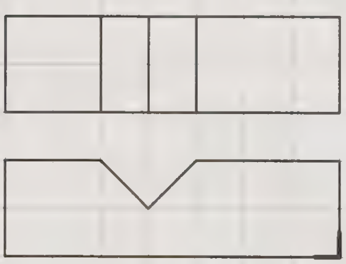
②



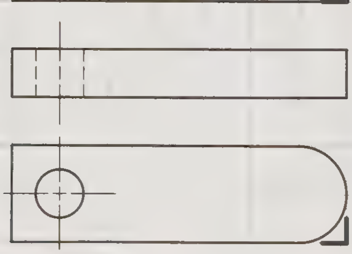
③



④



⑤

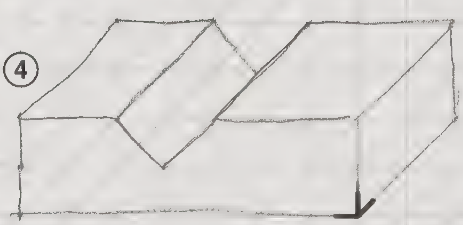


①

②

③

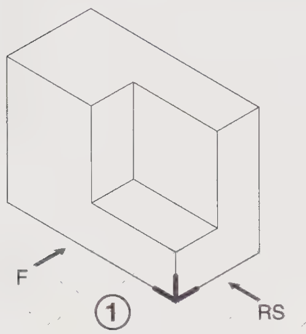
④



⑤

Sketching — Front and Right Side Views

Sketch the front and right side views of each isometric.

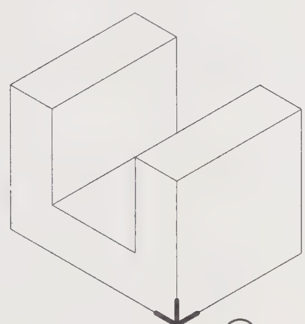


1

1

FRONT

RIGHT SIDE

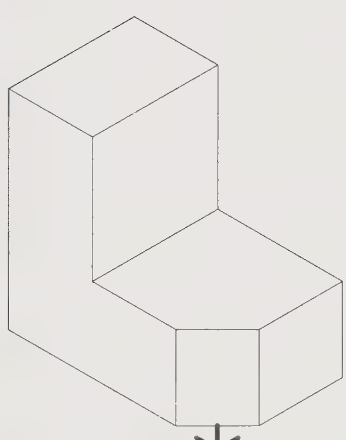


2

2

FRONT

RIGHT SIDE

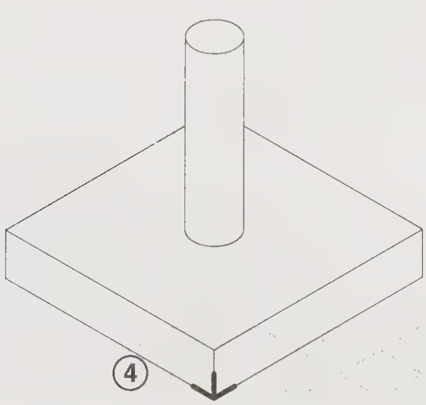


3

3

FRONT

RIGHT SIDE



4

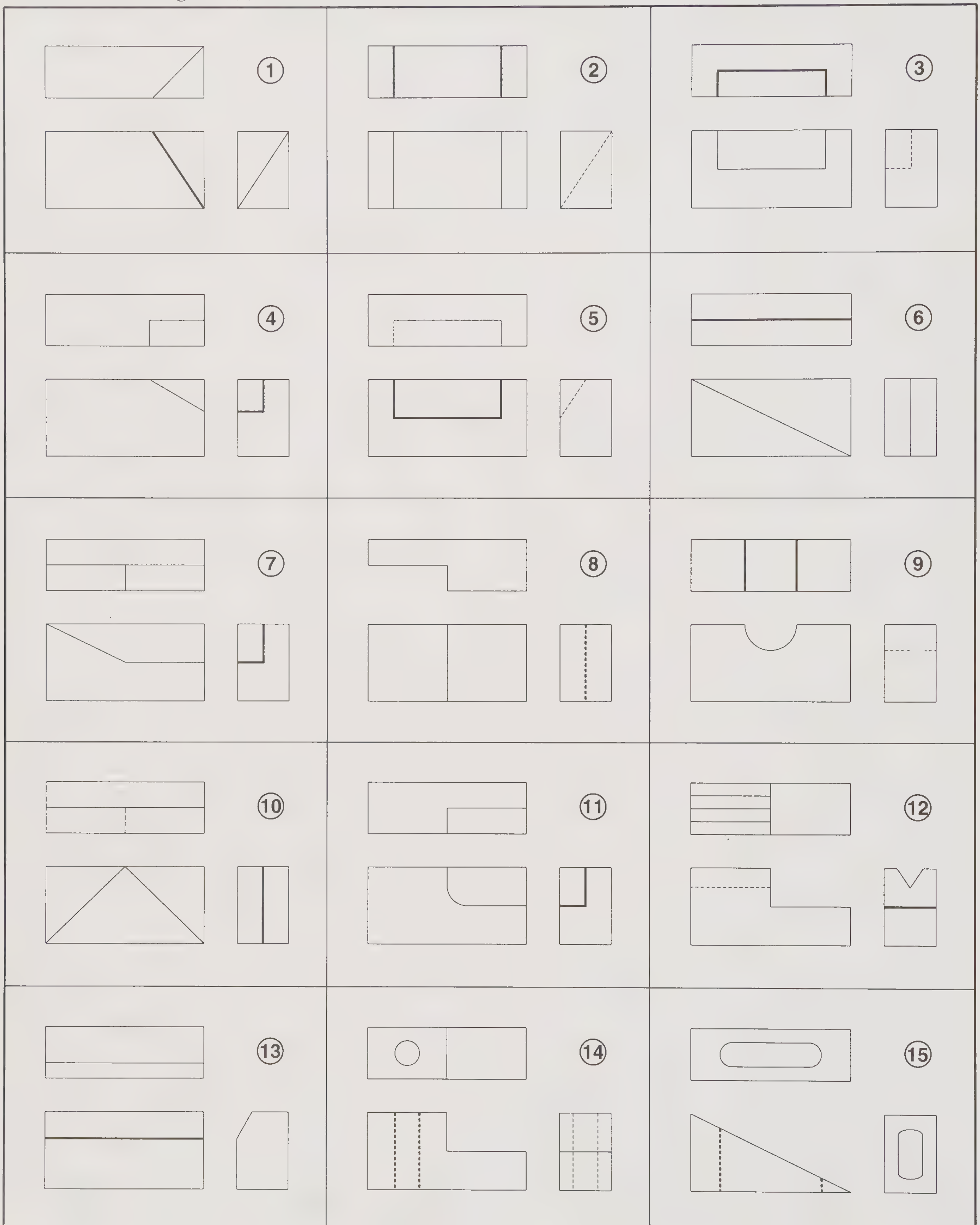
4

FRONT

RIGHT SIDE

Sketching — Multiviews (Missing Line)

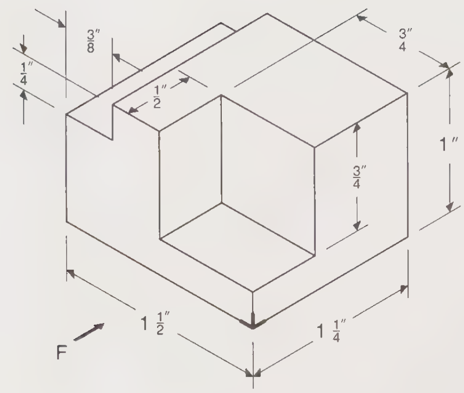
Sketch the missing line(s) of the multiviews.



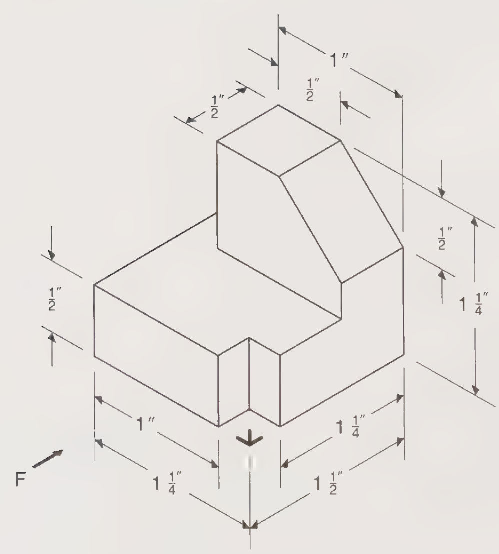
Sketching — Multiview Drawings

Sketch front, top, and right side views of the isometrics. Allow ½″ between views.

1

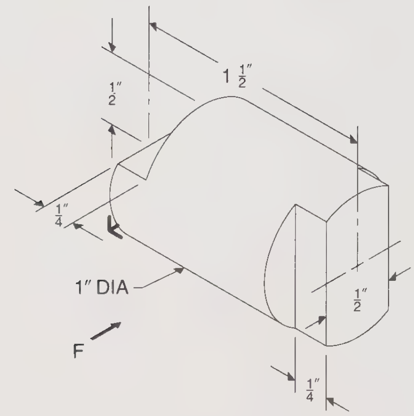


2

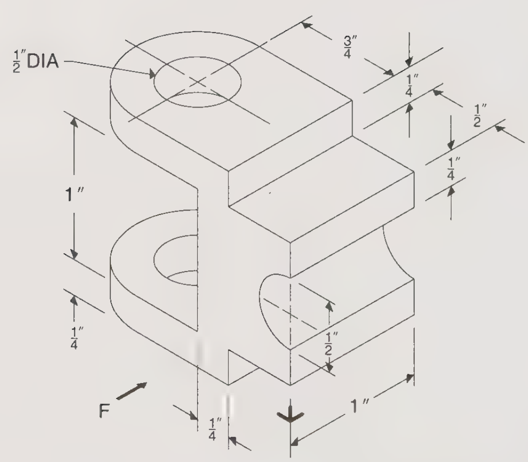


Sketching — Multiview Drawings (continued)

③



④



Ø6 A1

Review Questions

Name ______________________________ Date ______________

True-False

T F 1. Sketching pencils may be wooden or mechanical.

T F 2. Size B paper is 17″ × 22″.

T F 3. The pencil point should be pulled across the paper while sketching.

T F 4. Shading techniques are used with orthographic drawings.

T F 5. Perspective drawings are seldom used on machine trades prints.

T F 6. Oblique drawings show one surface of an object as a true view.

T F 7. Object lines are thin and dark.

T F 8. Break lines conserve space on drawings.

T F 9. Hole sizes are specified by their diameters.

T F 10. Spotfaces are commonly 1/8″ deep.

T F 11. A circle on an isometric drawing appears as an ellipse.

T F 12. The front view of an object is normally the view that shows the most shape.

T F 13. A cavalier drawing is a type of isometric drawing.

T F 14. Each view of an object is shown two-dimensionally in a multiview drawing.

T F 15. Always use symbols for math operations.

Completion

__________ 1. An axonometric drawing shows ________ sides of an object.

__________ 2. Isometric drawings contain three equal axes that are drawn ________° apart.

__________ 3. A(n) ________ is a plane curve with two focal points.

__________ 4. A(n) ________ oblique drawing has receding lines drawn to one-half the scale of lines in the true view.

__________ **5.** __________ projection, or multiview drawing, is drawing at right angles.

__________ **6.** The __________ view of a multiview drawing shows length and height.

__________ **7.** __________ lines define the visible shape of an object.

__________ **8.** __________ lines are terminated by arrowheads on both ends.

__________ **9.** A(n) __________ surface is a plane surface parallel to a plane of projection.

__________ **10.** A(n) __________ hole is a drilled hole that does not pass through the material.

__________ **11.** A(n) __________ hole is an enlarged and recessed hole with square shoulders.

__________ **12.** A(n) __________ is a rounded interior corner.

__________ **13.** A(n) __________ is a rounded exterior corner.

__________ **14.** __________ views show internal features of an object more clearly than they could be shown with hidden lines.

__________ **15.** A(n) __________ is a standard method of showing shortened views of elongated objects.

Matching — Alphabet of Lines

__________ **1.** Object lines

__________ **2.** Cutting plane line

__________ **3.** Short break line

__________ **4.** Long break line

__________ **5.** Hidden line

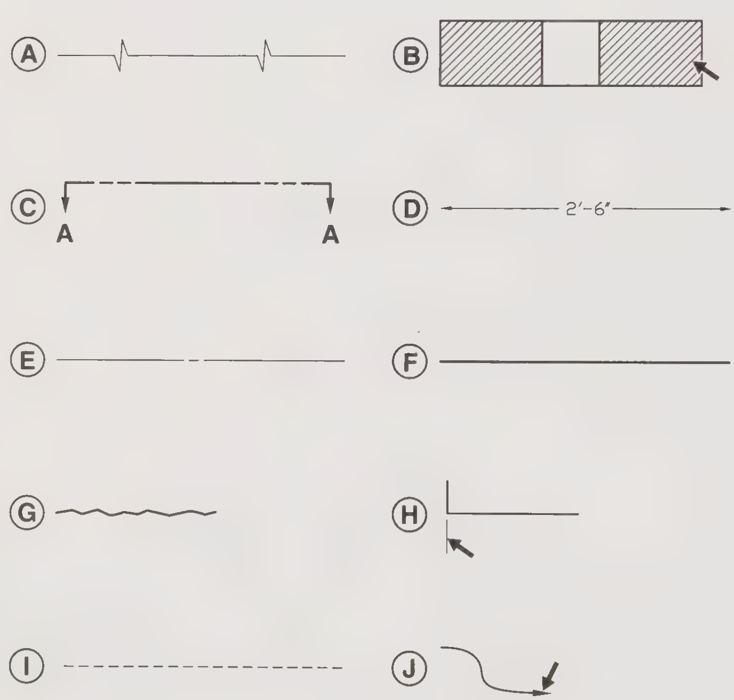
__________ **6.** Center line

__________ **7.** Dimension line

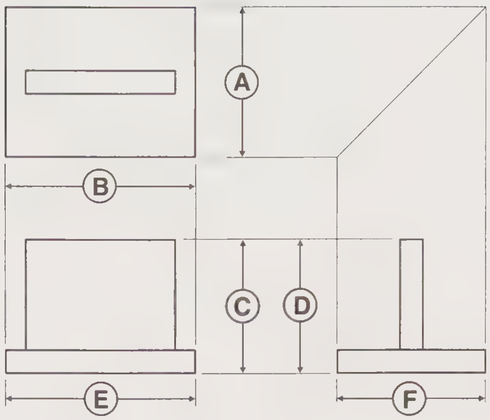
__________ **8.** Section line

__________ **9.** Extension line

__________ **10.** Arrowhead



Matching — Orthographic Projection



_____ 1. Front view - height

_____ 2. Front view - length

_____ 3. Top view - depth

_____ 4. Right side view - depth

_____ 5. Top view - length

_____ 6. Right side view - height

Multiple Choice

_____ **1.** A true view is a view in which the _________.

A. line of sight is parallel to the surface
B. surface can be completely seen
C. line of sight is perpendicular to the surface
D. neither A, B, nor C

_____ **2.** Arrows on the end(s) of the cutting plane line of a section view indicate the _________.

A. size of the section view
B. direction from the multiview to the section view
C. direction of sight
D. A, B, and C

_____ **3.** A spotface is _________.

A. a flat surface
B. either slightly above or below the surrounding surface
C. abbreviated by the letters SF
D. A, B, and C

_____ **4.** Twist drill sizes are designated by numbers _________.

A. 1 through 40
B. 10 through 40
C. 1 through 80
D. 10 through 80

_____ **5.** _________ surfaces are created when one surface meets another surface.

A. Inclined
B. Intersecting
C. Oblique
D. Normal

______ **6.** Break lines may be drawn as ______.

A. thick, dark freehand lines
B. thin, dark lines with a zig-zag every ¾″ to 1½″
C. both A and B
D. neither A nor B

______ **7.** Angular dimensions may be expressed as ______.

A. degrees and decimal parts of a degree
B. inches and fractional parts of an inch
C. both A and B
D. neither A nor B

______ **8.** Any one view of a multiview can show ______ dimension(s).

A. one
B. two
C. three
D. four

______ **9.** ______ are numerical values that give size, form, or location of objects.

A. Abbreviations
B. Symbols
C. Dimensions
D. neither A, B, nor C

______ **10.** The letter near the end of a cutting plane line indicates ______.

A. the direction of size
B. order of operation
C. the section view
D. neither A, B, nor C

Identification — Holes

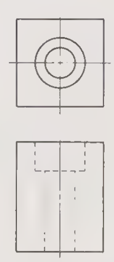
______ **1.** Drilled hole

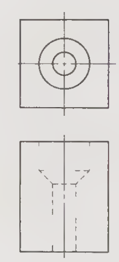
______ **2.** Drilled and counterbored hole

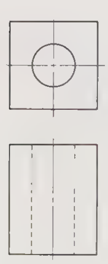
______ **3.** Drilled and countersunk hole

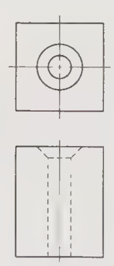
______ **4.** Drilled and counterdrilled hole

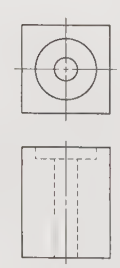
______ **5.** Drilled and spotfaced hole


(A)


(B)


(C)


(D)


(E)

◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Flat Wrench (*See page 38.*)

______ **1.** The Flat Wrench is designed for use with a(n) ________ head bolt.

______ **2.** The overall length of the Flat Wrench is ________″.

______ **3.** Both ends of the Flat Wrench are ________.

______ **4.** Two ________ views of the Flat Wrench are shown.

______ **5.** The drawing was drawn on ________ by WJR.

T F **6.** Sharp corners are to be ground.

T F **7.** The Flat Wrench is finished with a rust preventive coating.

T F **8.** The offset in the Flat Wrench is shown with an angular dimension.

______ **9.** Line A is a(n) ________ line.

______ **10.** Line B is a(n) ________ line.

______ **11.** Line C is a(n) ________ line.

______ **12.** Line D is a(n) ________ line.

T F **13.** Decimal and fractional dimensions are used to dimension the Flat Wrench.

______ **14.** The overall width of the Flat Wrench is ________″.

______ **15.** The company logo is to be stamped onto the Flat Wrench per spec ________.

______ **16.** The hexagon is ________″ across flats.

______ **17.** A total of ________ gussets is specified.

______ **18.** The maximum thickness of the Flat Wrench is ________″.

T F **19.** The Flat Wrench is heat treated.

T F **20.** The maximum offset angle is 67°.

Left Vertical Bracket

_________ **1.** The dimension at C is _________″.

_________ **2.** The center-to-center dimension at J is _________″.

_________ **3.** The edge-to-edge dimension at D is _________″.

_________ **4.** The radius dimension at B is _________″.

_________ **5.** The center-to-center dimension at E is _________″.

_________ **6.** The center-to-center dimension at F is _________″.

_________ **7.** The edge-to-center dimension at I is _________″.

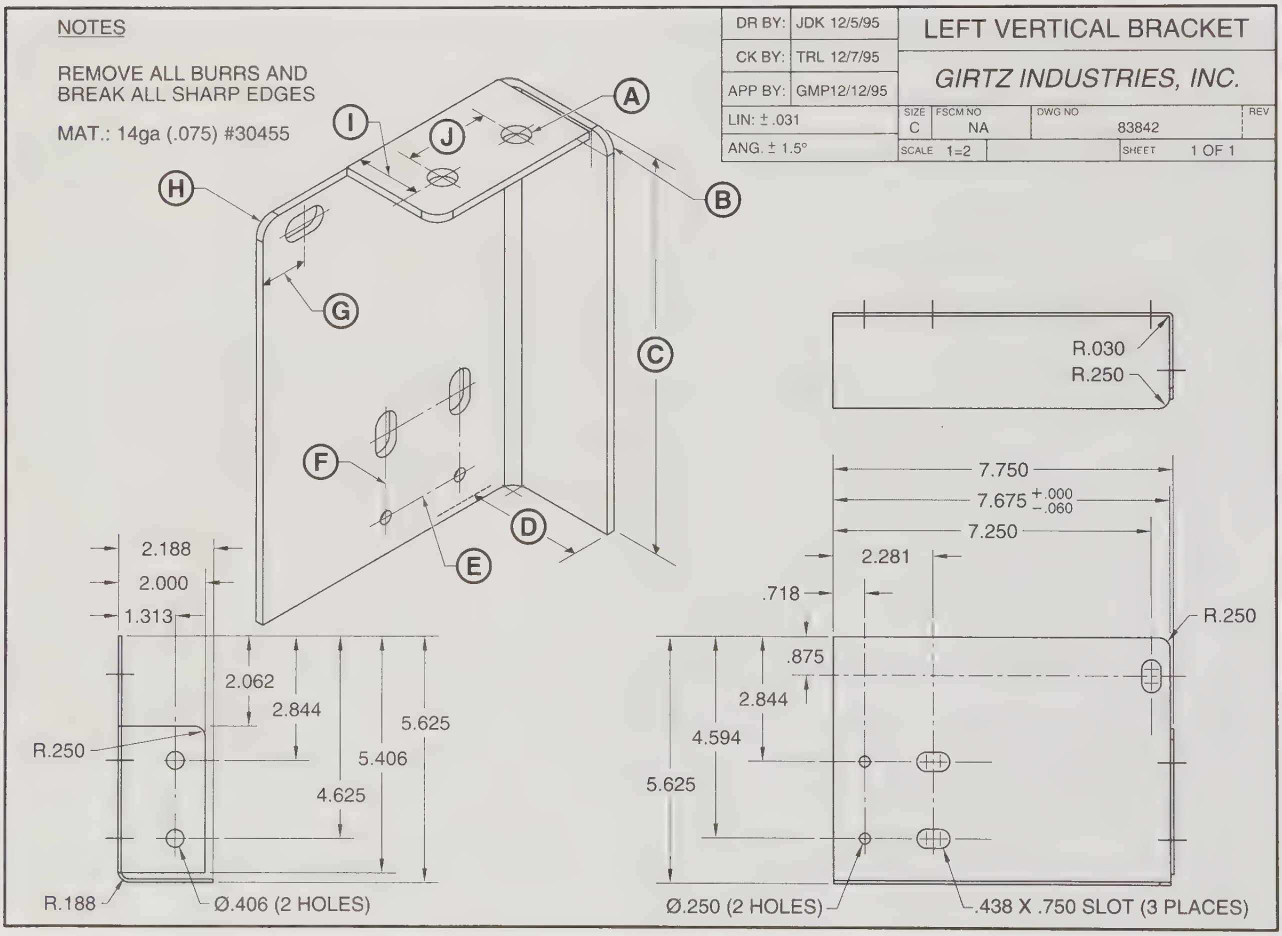
_________ **8.** The edge-to-center dimension at G is _________″.

_________ **9.** The radius dimension at H is _________″.

_________ **10.** The diameter of the hole at A is _________″.

_________ **11.** The maximum center-to-center dimension between the two adjacent slots is _________″.

T F **12.** The orthographic views shown include the top, front, and right side.



LEFT VERTICAL BRACKET

chapter 3

SHOP MATH

Machinists use basic math concepts to estimate material and labor costs and to perform layout and machining operations. Whole numbers and common or decimal fractions in English or Metric measurement systems are added, subtracted, multiplied, or divided to find solutions to problems. Sums, remainders, percentages, measurements, area of plane figures, and volume of solid figures are found by applying the proper math function(s).

WHOLE NUMBERS

Whole numbers are all numbers that have no fractional or decimal parts. For example, numbers such as 1, 2, 19, 46, 67, 328, etc. are whole numbers. *Odd numbers* are any numbers that cannot be divided by 2 an exact number of times. For example, numbers such as 1, 3, 5, 57, 109, etc. are odd numbers. *Even numbers* are any numbers that can be divided by 2 an exact number of times. For example, numbers such as 2, 4, 6, 48, 432, etc. are even numbers. See Figure 3-1.

Prime numbers are numbers that can be divided an exact number of times only by themselves and the number 1. For example, numbers such as 1, 2, 3, 5, 7, 11, 13, 17, 19, 23, etc. are prime numbers. Arabic and Roman numerals are the two common numeral systems used for calculations and notations.

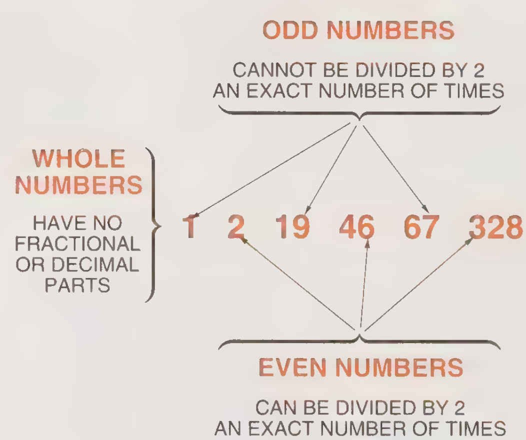


Figure 3-1. Whole numbers have no fractional or decimal parts.

Arabic Numerals

Arabic numerals are expressed by the ten digits 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. These digits may be used alone or in combination to represent quantities indicating how much, how many, how far, how long, how hot, how expensive, etc. This is the numeral system most commonly used in the United States. See Figure 3-2.

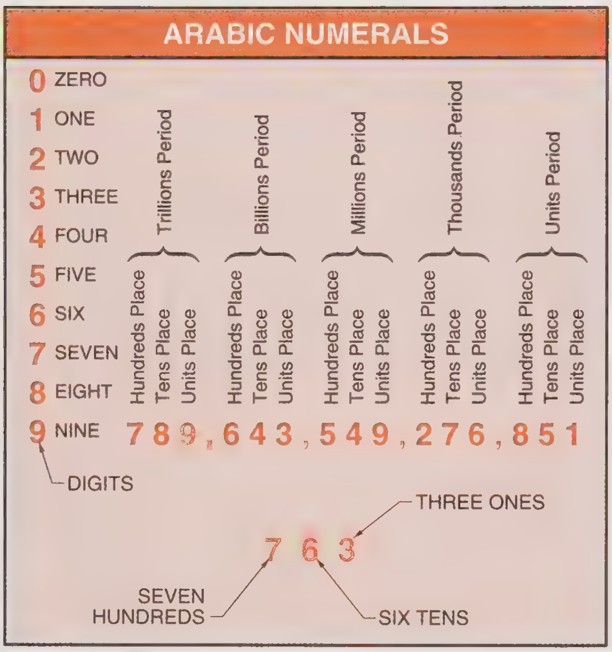


Figure 3-2. Arabic numerals are expressed by digits.

The Arabic numeral system is the most commonly used numeral system. Large Arabic numerals are made easier to read by the use of periods. A *period* is a group of three digits separated from other periods by a comma. The *units period* (000 through 999) is the first period. The *thousands period* (1,000 through 999,999) is the second period. The *millions period* (1,000,000 through 999,999,999) is the third period, etc.

Roman Numerals

Roman numerals are expressed by the letters I, X, L, C, D, and M. While not commonly used in the trades, this numeral system is occasionally seen as chapter numbers in a book, on clock faces, and on public buildings such as libraries, museums, etc. See Figure 3-3.

When a letter is followed by the same letter, or one lower in value, add the value of the letters. For example, XX = 20 and XV = 15. When a letter is followed by another letter greater in value, subtract the smaller letter. For example, IV = 4, IX = 9, and XC = 90.

When a letter is placed between two letters of greater value, subtract the smaller letter from the sum of the other two. For example, XIV = 14. A superscript rule (line above) placed over a letter increases the value of the letter a thousand times. For example:

$\overline{V}$ = 5,000

$\overline{X}$ = 10,000

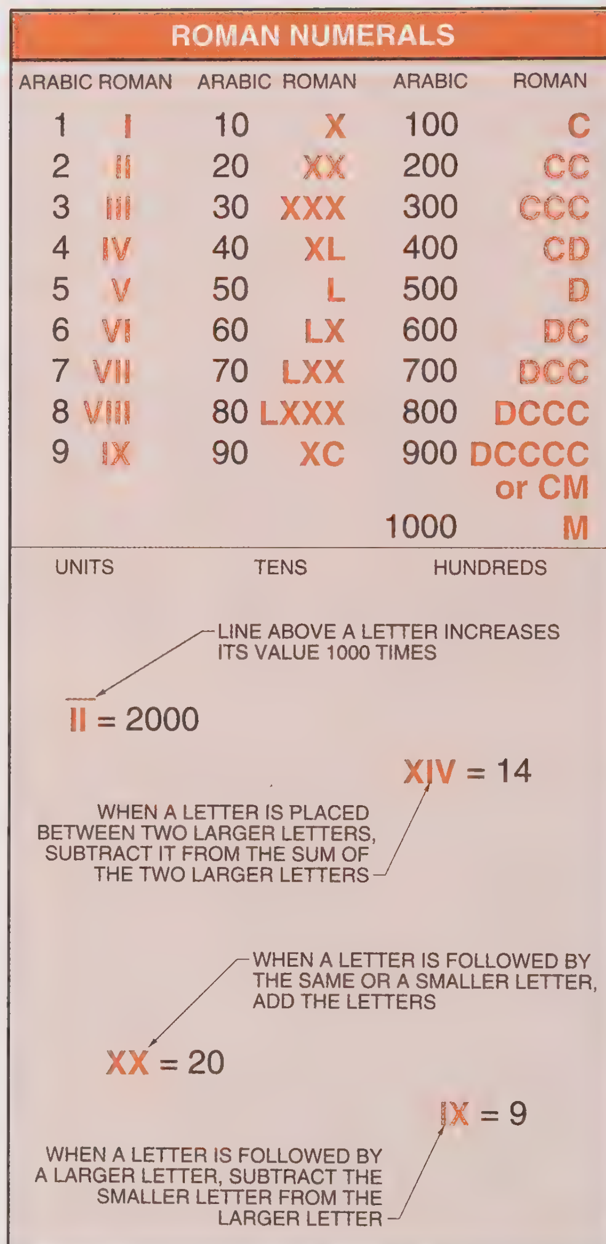


Figure 3-3. Roman numerals are expressed by letters.

Measurement Systems

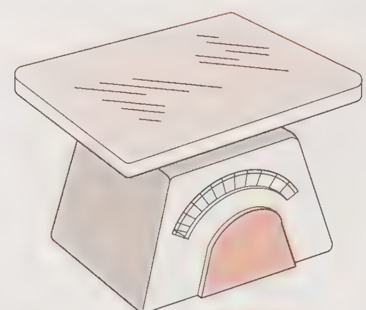
Three common systems of measurement are the British (U.S.) System, Decimal Inch System, and SI Metric System (International System of Units). Arabic numerals are used with these three measurement systems. The British (U.S.) System is also known as the English System and is the system in primary use in the United States. This system uses the inch, foot, and pound units of measurement. The Decimal Inch System is based on tenths and hundredths to simplify measurements. The Decimal Inch System is used by surveyors, scientists, engineers, etc.

The Metric System is the most common measurement system used in most of the world. Prefixes are used in the Metric System to represent multipliers. For example, the distance of 3,000 meters is expressed as 3 kilometers. Metric measurements are converted to English measurements (and vice versa) by applying the appropriate conversion factors. See Figure 3-4. See Appendix.

BASE UNITS

UNIT	SI SYMBOL	QUANTITY
Meter	m	Length
Gram	g	Mass
Second	s	Time
Ampere	A	Electric current

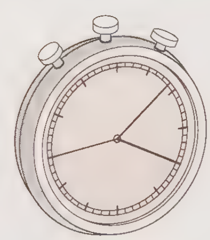
LENGTH



MASS

UNIT PREFIXES

PREFIX	UNIT	SYMBOL	NUMBER
Other larger multiples			
Mega	Million	M	$1,000,000 = 10^6$
Kilo	Thousand	k	$1,000 = 10^3$
Hecto	Hundred	h	$100 = 10^2$
Deka	Ten	d	$10 = 10^1$
			Unit $1 = 10^0$
Deci	Tenth	d	$0.1 = 10^{-1}$
Centi	Hundreth	c	$0.01 = 10^{-2}$
Milli	Thousandth	m	$0.001 = 10^{-3}$
Micro	Millionth	μ	$0.000001 = 10^{-6}$
Other smaller multiples			



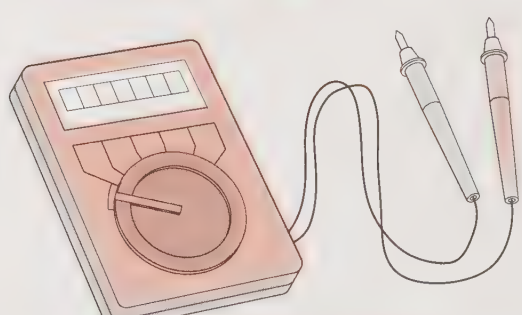
TIME

EXAMPLES

COMBINE UNIT PREFIX SYMBOL
AND BASE UNIT SYMBOL

mm = millimeter
kg = kilogram
mA = milliamp

UNIT PREFIX SYMBOL
BASE UNIT SYMBOL



ELECTRIC CURRENT

Figure 3-4. The Metric System is the common measurement system used in most of the world.

Addition

Addition is the process of uniting two or more numbers to make one number. It is the most common operation in mathematics. The sign + (plus) indicates addition and is used when numbers are added horizontally or when two numbers are added vertically. When more than two numbers are added vertically, the operation is apparent, and no sign is required. The *sum* is the result obtained from adding two or more numbers.

To add whole numbers vertically, place all numbers in aligned columns. The units must be in the ones (units) column, tens in the tens column, hundreds in the hundreds column, etc. Add the columns from top to bottom, beginning with the ones column. When the sum of the numbers in the ones column is 0 – 9, record the sum and add the tens column. When the sum of the numbers in the ones column is 10 or more, record the last digit and carry the remaining digit(s) to the tens column. Follow this same procedure for remaining columns.

To add whole numbers horizontally is more difficult than adding them vertically. For example, 25 + 120 + 37 + 3 = 185 shows whole numbers added horizontally. This method is not as commonly used as the vertical alignment method because mistakes can occur more easily.

Check vertically aligned addition problems by adding the numbers from bottom to top. Check horizontally aligned addition problems by adding the numbers from right to left. The same sum will occur if both operations have been added correctly. See Figure 3-5.

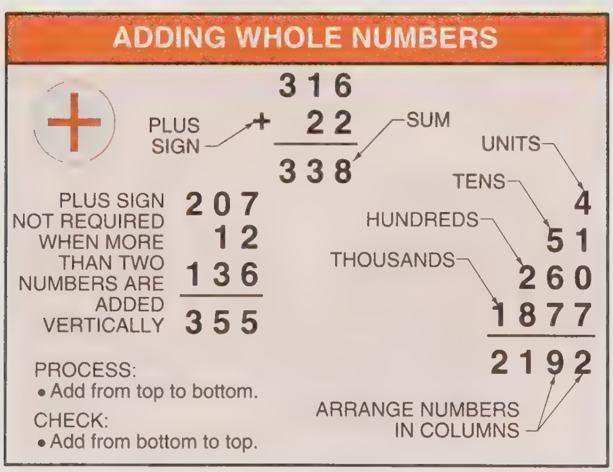


Figure 3-5. Addition is the process of uniting two or more numbers to make one number.

Subtraction

Subtraction is the process of taking one number away from another number. It is the opposite of addition. The sign – (minus) indicates subtraction. The *minuend* is the number from which the subtraction is made. The *subtrahend* is the number which is subtracted. The *remainder* is the difference between the two. Place the minuend above the subtrahend when vertically aligning numbers.

As in addition, the first column of numbers represents ones, the second column represents tens, etc. Whenever a subtrahend digit is larger than the corresponding minuend digit, borrow one unit (tens, hundreds, etc.) from the column immediately to the left and continue the operation. For example, when subtracting 8 from 24, borrow a 1 from the tens column, subtract 8 from 14, record the 6 in the units column, and record the remaining 1 in the tens column for a remainder of 16. See Figure 3-6.

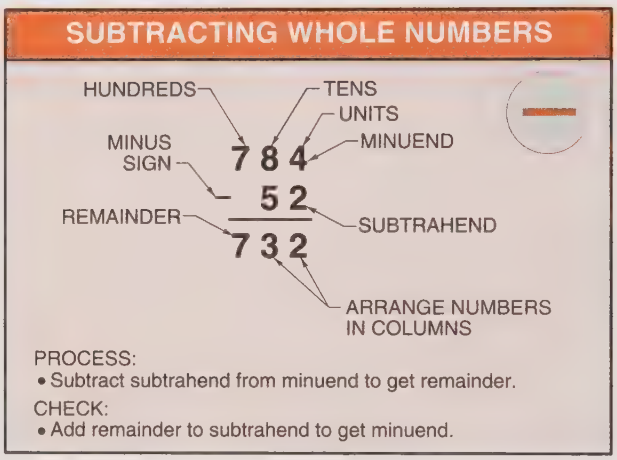


Figure 3-6. Subtraction is the process of taking one number away from another number.

Multiplication

Multiplication is the process of adding one number as many times as there are units in the other number. For example, 3 × 4 = 12 produces the same result as adding 4 + 4 + 4 = 12. The sign × (times or multiplied by) indicates multiplication. The *multiplicand* is the number which is multiplied. The *multiplier* is the number by which multiplication is done. The *product* is the result of the multiplication.

The larger number is commonly used as the multiplicand when the units being multiplied are

the same. For example, 8′ × 4′ = 32′. If a number to be multiplied represents a unit of measurement (inches, feet, pounds, etc.), identify the unit of measurement in the multiplicand, multiplier, and product. Numbers may be arranged vertically (preferred) or horizontally when multiplying. An effective method of checking the product is to reverse the multiplicand and the multiplier and perform the operation again. The same product will occur if both operations have been multiplied correctly.

Zeros have no value, therefore any number multiplied by a zero equals zero. For example, 21 × 0 = 0. To multiply a multiplicand by 10, add one zero. For example, to multiply 74 by 10, add one zero to the 74 to get 740 (74 × 10 = 740). Add two zeros to multiply by 100, etc. See Figure 3-7.

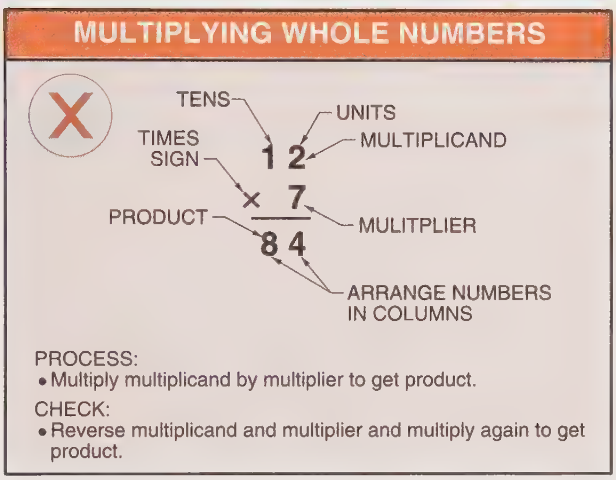


Figure 3-7. Multiplication is the process of adding one number as many times as there are units in the other number.

Division

Division is the process of finding how many times one number contains the other number. It is the reverse of multiplication. The sign ÷ (divided by) indicates division. The sign $\overline{)\quad}$ also indicates division. The *dividend* is the number to be divided. The *divisor* is the number by which division is done. The *quotient* is the result of the division. The *remainder* is the part of the quotient left over whenever the quotient is not a whole number.

To divide a number by 10, 100, etc. remove as many places from the right of the dividend as their are zeros in the divisor. For example, 500 ÷ 10 = 50. Notice that one zero was removed from the dividend (500) to yield the quotient of 50.

Any remainder is placed over the divisor and expressed as a fraction. For example, 27 ÷ 4 = $6\frac{3}{4}$. Notice that 4 goes into 27 six times with a remainder of 3. The 3 is placed over the 4 (divisor).

To check division, multiply the divisor by the quotient. For example, 48 ÷ 4 = 12. To check this problem, multiply 4 (divisor) by 12 (quotient). For example, 4 × 12 = 48. See Figure 3-8.

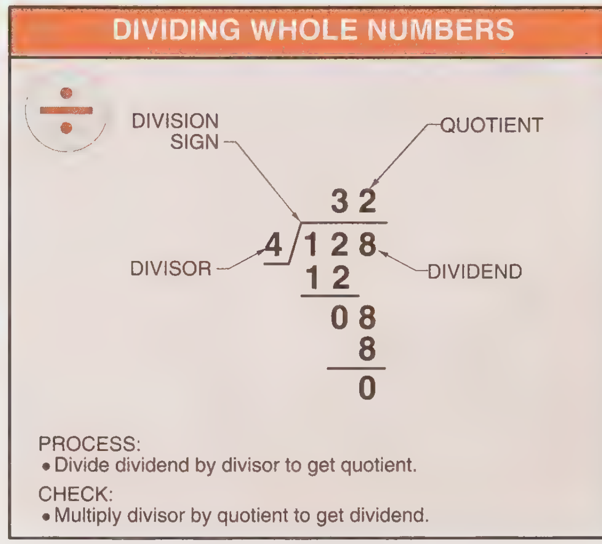


Figure 3-8. Division is the process of finding how many times one number contains the other number.

COMMON FRACTIONS

A *fraction* is one part of a whole number. The number 1 is the smallest whole number. Anything smaller than 1 is a fraction and can be divided into any number of fractional parts. Fractions are written above and below or on both sides of a fraction bar. Fraction bars may be horizontal or inclined.

The *denominator* shows how many parts the whole number has been divided into. The denominator is the lower (or right-hand) number of a fraction. The *numerator* shows the number of parts in the fraction. The numerator is the upper (or left-hand) number. For example, the fraction $\frac{3}{4}$ shows that a whole number is divided into four equal parts (denominator), and three of these parts (numerator) are present.

A *proper fraction* has a denominator larger than its numerator. An *improper fraction* has a numerator larger than its denominator. A *mixed number* is a combination of a whole number and a fraction.

For example, ¾ is a proper fraction, 5/4 is an improper fraction, and 1¼ is a mixed number.

Any type of units can be divided into fractional parts. For example, inches are commonly divided into fractional parts of an inch based upon halves, fourths, eighths, sixteenths, thirty-seconds, and sixty-fourths. Fractional parts of an inch are always expressed in their lowest common denominator.

The *lowest common denominator (LCD)* is found by dividing the highest number that will divide equally into the denominator and numerator. For example, the LCD of the fraction 12/16 is ¾. This is obtained by dividing 4 into 12 and 4 into 16. Always reduce fractions to their lowest common denominators. See Figure 3-9.

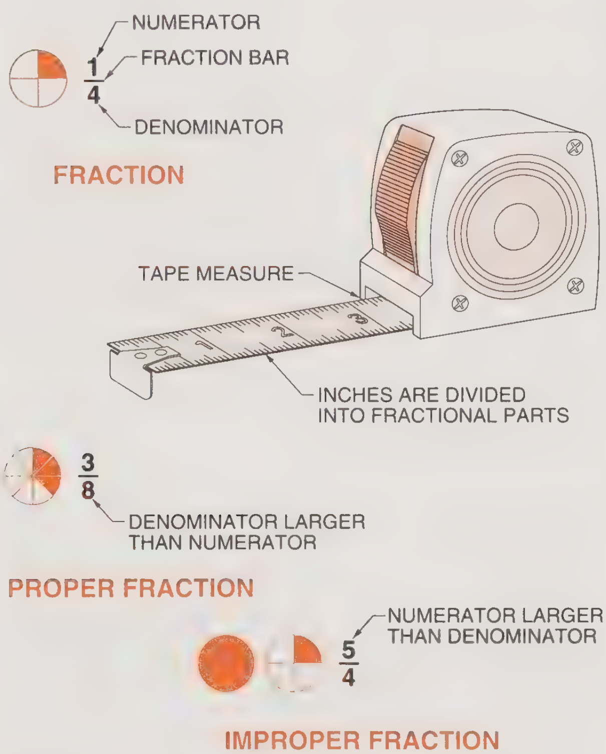


Figure 3-9. A fraction is one part of a whole number.

Addition

Fractions may be added horizontally or vertically. Horizontal placement is the most common, as identification of numerators and denominators is easier. Fractions which may be added include proper fractions, improper fractions, mixed numbers, and fractions with unlike denominators. There is a different rule for each of these four combinations. See Figure 3-10.

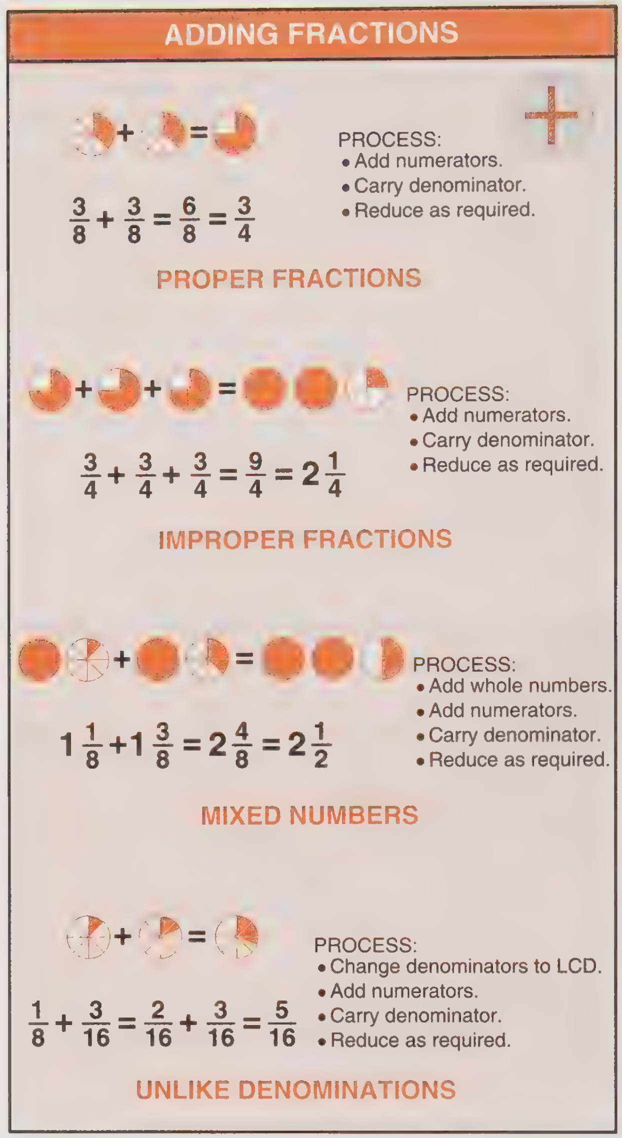


Figure 3-10. Fractions which may be added include proper fractions, improper fractions, mixed numbers, and fractions with unlike denominators.

Adding Proper Fractions. Fractions having the same denominator are added by adding the numerators and placing them over the denominator. For example, in the problem ⅓ + ⅓ = ⅔, the numerators (1 + 1) are added to produce 2. The denominator (3) remains constant.

Adding Improper Fractions. Fractions which produce a sum in which the numerator is larger than the denominator (improper fractions) are changed to a mixed number by dividing the numerator by the denominator, recording the quotient

obtained, and treating the remainder as a numerator placed over the original denominator. For example, in the problem $\frac{3}{8} + \frac{3}{8} + \frac{3}{8} = \frac{9}{8}$, the improper fraction ($\frac{9}{8}$) is changed to $1\frac{1}{8}$ by dividing 9 by 8. The fraction is then written $\frac{3}{8} + \frac{3}{8} + \frac{3}{8} = \frac{9}{8} = 1\frac{1}{8}$.

Adding Mixed Numbers. To add fractions containing mixed numbers, add the whole numbers, add the numerators, and carry the denominator. For example, in the problem $1\frac{1}{4} + 3\frac{1}{4} + 4\frac{1}{4} = 8\frac{3}{4}$, the whole numbers $(1 + 3 + 4)$ are added to produce 8. The numerators $(1 + 1 + 1)$ are added to produce 3, which is placed over the denominator 4.

Adding Fractions with Unlike Denominators. To add fractions in which the denominators are not the same, change the denominators to the LCD, add the numerators, and carry the denominator. If an improper fraction occurs, change the improper fraction to a mixed number. For example, to add $\frac{3}{8} + \frac{1}{2} + \frac{3}{4}$, change the denominators to 8 and multiply the number of times the original denominators will go into 8 by the numerators to get $\frac{3}{8} + \frac{4}{8} + \frac{6}{8}$. Add the numerators $3 + 4 + 6 = 13$ and place over the denominator to get $\frac{13}{8}$. Change the improper fraction $\frac{13}{8}$ by dividing 13 by 8. Thirteen can be divided by 8 one time with a remainder of 5, which is placed over the 8 to produce $1\frac{5}{8}$ ($\frac{3}{8} + \frac{1}{2} + \frac{3}{4} = \frac{3}{8} + \frac{4}{8} + \frac{6}{8} = \frac{13}{8} = 1\frac{5}{8}$).

Subtraction

Subtraction of fractions is similar to addition of fractions. Fractions may be subtracted horizontally or vertically. Horizontal placement is the most common, as identification of numerators and denominators is easier. All fractions must have a common denominator before one can be subtracted from another. Fractions which may be subtracted include fractions with like denominators, fractions with unlike denominators, and mixed numbers. There is a different rule for each of these three combinations. See Figure 3-11.

Subtracting Fractions with Like Denominators. To subtract fractions having the same denominators, subtract one numerator from the other numerator and place over the denominator. For example, to subtract $\frac{7}{16}$ from $\frac{11}{16}$, subtract the numerator 7 from the numerator 11 to get 4. Place the 4 over the denominator 16. Reduce $\frac{4}{16}$ by dividing by the largest number that will go into the numerator and denominator an even number of times. In this example, divide the numerator and denominator by 4 to get $\frac{1}{4}$ ($\frac{11}{16} - \frac{7}{16} = \frac{4}{16} = \frac{1}{4}$).

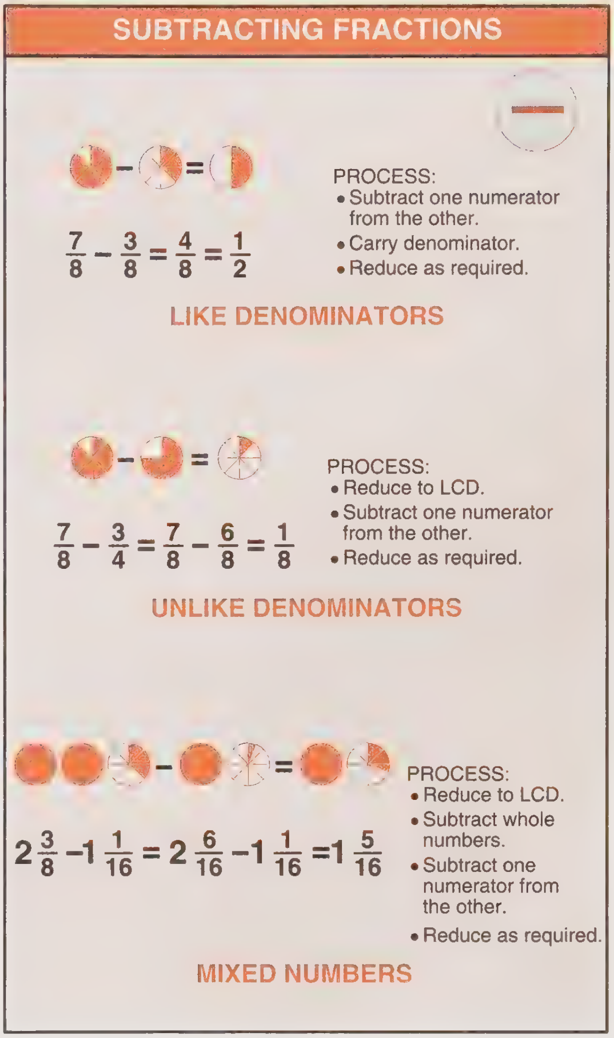


Figure 3-11. Fractions which may be subtracted include fractions with like denominators, fractions with unlike denominators, and mixed numbers.

Subtracting Fractions with Unlike Denominators. To subtract fractions having unlike denominators, reduce the fractions to their LCD and subtract one numerator from the other. For example, to subtract $\frac{7}{16}$ from $\frac{3}{4}$, reduce $\frac{3}{4}$ to $\frac{12}{16}$ and subtract $\frac{7}{16}$ to get $\frac{5}{16}$ ($\frac{3}{4} - \frac{7}{16} = \frac{12}{16} - \frac{7}{16} = \frac{5}{16}$).

Subtracting Mixed Numbers. To subtract fractions having mixed numbers, follow the applicable

procedure for denominators, subtract the numerators, subtract the whole numbers, and if necessary, reduce the fraction to its lowest common denominator. For example, to subtract $1\frac{1}{4}$ from $3\frac{1}{2}$, reduce the fractions to their LCD and subtract one numerator from another to get $\frac{2}{4} - \frac{1}{4} = \frac{1}{4}$. Subtract the whole numbers to get $3 - 1 = 2$. Add the whole number and the fraction to get $2 + \frac{1}{4} = 2\frac{1}{4}$.

Multiplication

Fractions may be multiplied horizontally or vertically. Horizontal placement of fractions is the most common, as identification of numerators and denominators is easier. Fractions which may be multiplied include two fractions, fractions and a whole number, a mixed number and a whole number, and two mixed numbers. There is a different rule for each of these four combinations. See Figure 3-12.

Multiplying Two Fractions. To multiply two fractions, multiply the numerator of one fraction by the numerator of the other fraction. Do the same with the denominators. Reduce the answer as required. For example, to multiply $\frac{3}{8}$ by $\frac{1}{8}$, multiply the numerators to get 3 ($3 \times 1 = 3$) and multiply the denominators to get 64 ($8 \times 8 = 64$). Thus, $\frac{3}{8} \times \frac{1}{8} = \frac{3}{64}$.

Multiplying Fractions and a Whole Number. To multiply a fraction and a whole number, multiply the numerator of the fraction by the whole number and place over the denominator. Reduce the answer as required. For example, to multiply $\frac{1}{8} \times 3$, multiply the numerator 1×3 (whole number) to get 3 ($1 \times 3 = 3$) and place the 3 over the denominator 8 to get $\frac{3}{8}$. Thus, $\frac{1}{8} \times 3 = \frac{3}{8}$.

Multiplying a Mixed Number and a Whole Number. To multiply a mixed number and a whole number, multiply the fraction of the mixed number by the whole number, multiply the whole numbers, and add the two products. For example, to multiply $4\frac{7}{8} \times 3$, multiply $\frac{7}{8}$ (fraction of the mixed number) by 3 (whole number) to get $2\frac{5}{8}$ ($\frac{7}{8} \times 3 = \frac{21}{8} = 2\frac{5}{8}$). Multiply the whole numbers to get 12 ($4 \times 3 = 12$) and add the two products to get $14\frac{5}{8}$ ($2\frac{5}{8} + 12 = 14\frac{5}{8}$). Thus, $4\frac{7}{8} \times 3 = 14\frac{5}{8}$.

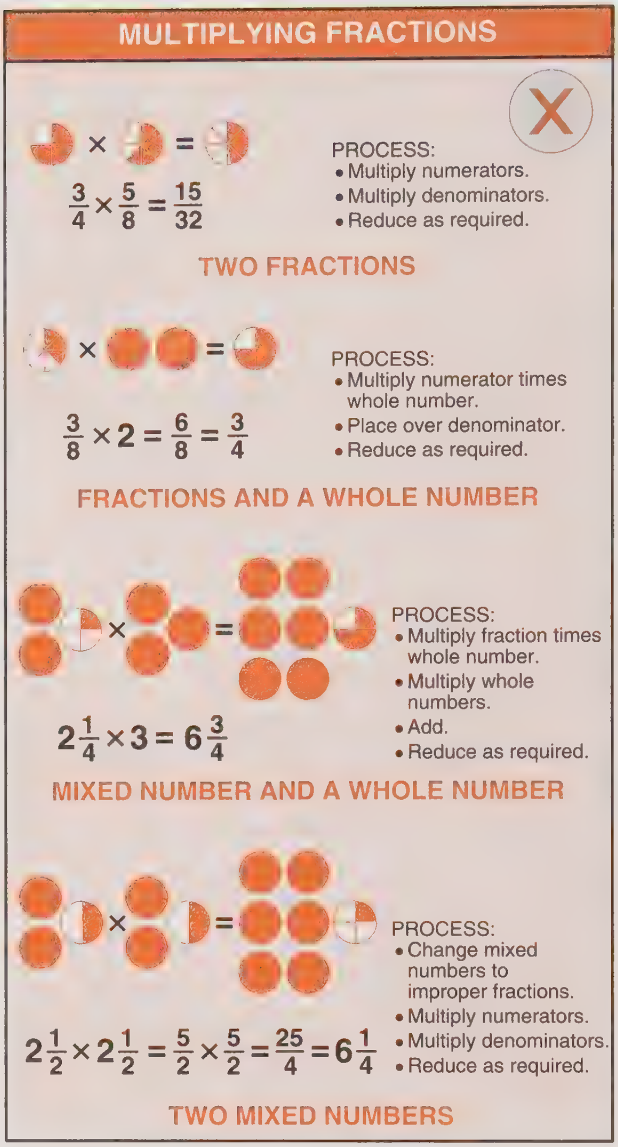


Figure 3-12. Fractions which may be multiplied include two fractions, fractions and a whole number, a mixed number and a whole number, and two mixed numbers.

Multiplying Two Mixed Numbers. To multiply two mixed numbers, change both mixed numbers to improper fractions and multiply. For example, to multiply $3\frac{1}{4}$ by $4\frac{1}{2}$, change the mixed number $3\frac{1}{4}$ to the improper fraction $\frac{13}{4}$ by multiplying the whole number 3 by the denominator 4 and adding the 1 ($3 \times 4 = 12 + 1 = \frac{13}{4}$). Change the mixed number $4\frac{1}{2}$ to the improper fraction $\frac{9}{2}$ by multiplying the whole number 4 by the denominator 2 and adding the 1 ($4 \times 2 = 8 + 1 = \frac{9}{2}$). Multiply the improper fractions to get $12\frac{1}{8}$ ($\frac{13}{4} \times \frac{9}{2} = \frac{117}{8} = 14\frac{5}{8}$). Thus, $3\frac{1}{4} \times 4\frac{1}{2} = 14\frac{5}{8}$.

Division

Fractions are divided horizontally. Fractions which may be divided include a fraction by a whole number, a mixed number by a whole number, two fractions, a whole number by a fraction, and two mixed numbers. There is a different rule for each of these five combinations. See Figure 3-13.

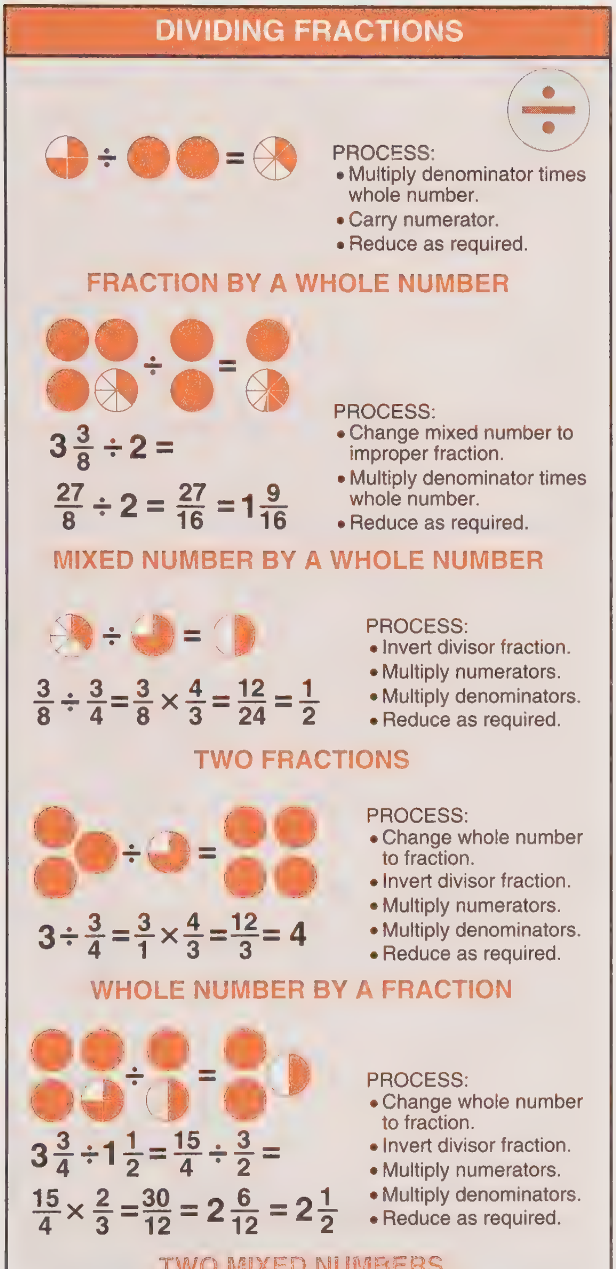


Figure 3-13. Fractions which may be divided include a fraction by a whole number, a mixed number by a whole number, two fractions, a whole number by a fraction, and two mixed numbers.

Dividing a Fraction by a Whole Number. To divide a fraction by a whole number, multiply the denominator of the fraction by the whole number. For example, to divide $3/8$ by 4, multiply the denominator 8 by the whole number 4 to get 32 ($8 \times 4 = 32$). Place the numerator 3 over the 32 to get $3/32$. Thus, $3/8 \div 4 = 3/32$.

Dividing a Mixed Number by a Whole Number. To divide a mixed number by a whole number, change the mixed number to an improper fraction and multiply the denominator of the improper fraction by the whole number. For example, to divide $2\,7/8$ by 3, change the mixed number $2\,7/8$ to $23/8$. Multiply the denominator of the improper fraction $23/8$ by the whole number 3 to get $23/24$. Thus, $2\,7/8 \div 3 = 23/24$.

Dividing Two Fractions. To divide two fractions, invert the divisor fraction and multiply the numerator by the numerator and the denominator by the denominator. For example, to divide $3/8$ by $1/4$, invert the divisor fraction $1/4$ and multiply by $3/8$ to get $1\,1/2$ ($3/8 \times 4/1 = 12/8 = 1\,4/8 = 1\,1/2$). Thus, $3/8 \div 1/4 = 1\,1/2$.

Dividing a Whole Number by a Fraction. To divide a whole number by a fraction, change the whole number into fraction form, invert the divisor fraction, and multiply the numerator by the numerator and the denominator by the denominator. For example, to divide 12 by $3/4$, change the whole number 12 to fraction form $12/1$. Invert the divisor fraction $3/4$ and multiply to get 16 ($12/1 \times 4/3 = 48/3 = 16$). Thus, $12 \div 3/4 = 16$.

Dividing Two Mixed Numbers. To divide two mixed numbers, change both mixed numbers to improper fractions, invert the divisor fraction, and multiply the numerator by the numerator and the denominator by the denominator. For example, to divide $12\,1/2$ by $3\,1/8$, change the mixed number $12\,1/2$ to $25/2$ and the mixed number $3\,1/8$ to $25/8$. Invert the divisor fraction $25/8$ and multiply to get 4 ($25/2 \times 8/25 = 200/50 = 4$). Thus, $12\,1/2 \div 3\,1/8 = 4$.

DECIMALS

A *decimal* is a fraction with a denominator of 10, 100, 1000, etc. The number 1 is the smallest whole number. Anything smaller than 1 is a decimal and can be divided into any number of decimal parts. For example, the decimal .75 shows that the whole number 1 is divided into 100 equal parts, and 75 of these parts are present. Any fraction with 10, 100, 1000, or other multiple of ten for the denominator, may be written as a decimal. For example, the fraction $\frac{1}{10}$ is .1 in decimals, $\frac{1}{100}$ is .01, and $\frac{1}{1000}$ is .001. See Figure 3-14.

A *decimal point* is the period in a decimal number. Shop workers and others who use decimals in their work often say "point" at the decimal point. For example, to denote 3.22, the worker says "three point twenty-two." This denotes $3\frac{22}{100}$. Others may say *and* at the decimal point. For example, to denote 4.37, they may say "four and thirty-seven hundredths." Both methods of expressing decimals are acceptable.

The United States monetary system is based on decimals. The dollar ($1.00) is valued at 100 cents. Each cent is $\frac{1}{100}$ of a dollar or $.01. Each nickel is $\frac{5}{100}$ of a dollar or $.05. Each dime is $\frac{10}{100}$ of a dollar or $.10. Each quarter is $\frac{25}{100}$ of a dollar or $.25. Each half-dollar is $\frac{50}{100}$ of a dollar or $.50.

More places written in a decimal indicate a higher degree of accuracy. For example, while .2 and .20 represent the same value, .20 is measured in hundredths and .2 is measured in tenths.

Adding or Subtracting Decimals

To add or subtract decimals, align the numbers vertically on the decimal points. Thus units will be added or subtracted to units, tenths to tenths, hundredths to hundredths, etc. Add or subtract as in whole numbers and place the decimal point of the sum or remainder directly below the other decimal points. For example, to add 27.08 and 9.127, align the numbers vertically on the decimal points and add to get 36.207.

Multiplying Decimals

To multiply decimals, multiply as in whole numbers. Then begin at the right of the product and point off to the left the same number of decimal places in the quantities multiplied.

DECIMALS

CURRENCY	VALUE	DECIMAL	FRACTION
DOLLAR BILL	$1.00	1.00	$\frac{100}{100}$
HALF-DOLLAR	50¢	.50	$\frac{50}{100}$
QUARTER	25¢	.25	$\frac{25}{100}$
DIME	10¢	.10	$\frac{10}{100}$
NICKEL	5¢	.05	$\frac{5}{100}$
PENNY	1¢	.01	$\frac{1}{100}$

Millions, Hundred Thousands, Ten Thousands, Thousands, Hundreds, Tens, Units, Tenths, Hundredths, Thousandths, Ten Thousandths, Hundred Thousandths, Millionths, Ten Millionths, Hundred Millionths, Billionths

NUMBER OF PLACES LEFT OR RIGHT OF DECIMAL POINT

7,654,321.123,456,789

DECIMAL POINT

$$\begin{array}{r} .35 \\ .03 \\ .16 \\ 1.08 \\ \hline 1.62 \end{array} \qquad \begin{array}{r} 12.55 \\ -\ 3.32 \\ \hline 9.23 \end{array}$$

PROCESS:
- Align decimal points.
- Add or subtract same as whole numbers.

ADDING OR SUBTRACTING DECIMALS

$$\begin{array}{r} 2.36 \\ \times .7 \\ \hline 1.652 \end{array}$$

POINT OFF DECIMAL PLACE

PROCESS:
- Multiply same as whole numbers.
- Point off decimal place.

MULTIPLYING DECIMALS

$$3.25 \overline{)\,9.75}$$

$$\begin{array}{r} 3. \\ 9\ 75 \\ \hline \end{array}$$

PROCESS:
- Divide same as whole numbers.
- Point off decimal place.

DIVIDING DECIMALS

Figure 3-14. A decimal is a fraction with a denominator of 10, 100, 1000, etc.

Prefix zeros when necessary. For example, to multiply 20.45 by 3.15, align the numbers vertically on the decimal points, multiply as in whole numbers, and point off four places from the right to get 64.4175.

Dividing Decimals

To divide decimals, divide as though dividend and divisor are whole numbers. Then point off from right to left as many decimal places as the difference between the number of decimal places in the dividend and divisor.

If the dividend has less decimal places than the divisor, add zeros to the dividend. There must be at least as many decimal places in the dividend as in the divisor. For example, to divide 2.5 into 16.75, divide as in whole numbers and point off one decimal place from right to left to get 6.7.

Changing Decimals to Common Fractions

To change a decimal to a common fraction, use the figures in the quantity as a numerator. For the denominator, place the figure 1 followed by as many zeros as there are figures to the right of the decimal point in the quantity. For example, to change the decimal .4 to a common fraction, place the 4 as a numerator and place a 1 followed by a zero as the denominator to get $^{4}/_{10}$.

To change the decimal .47 to a common fraction, place the 47 as a numerator and place a 1 followed by two zeros as the denominator to get $^{47}/_{100}$. To change the decimal .479 to a common fraction, place the 479 as a numerator and place a 1 followed by three zeros as the denominator to get $^{497}/_{1000}$.

PLANE FIGURES

A *plane figure* is a flat figure. It has no depth. Plane figures are the basis for sketching and drawing. All plane figures are composed of lines drawn at various angles or with arcs. Plane figures include circles, triangles, quadrilaterals, and polygons. A *regular plane figure* has equal angles and equal sides. An *irregular plane figure* does not have equal angles and equal sides.

Lines

A *straight line* is the shortest distance between two points. It is commonly referred to as a line. A *horizontal line* is parallel to the horizon. It is a level line. A *vertical line* is perpendicular to the horizon. Vertical, perpendicular, and plumb mean being at right angles to a baseline. *Vertical* is a line in a straight upward position. *Perpendicular* stresses the straightness of a line making a right angle with another (not necessarily horizontal) line. The symbol for perpendicular is ⊥. *Plumb* is an exact verticality (determined by a plumb bob and line) with Earth's gravity.

Lines may be drawn in any position. An *inclined (slanted) line* is neither horizontal nor vertical. *Parallel lines* remain the same distance apart. The symbol for parallel lines is ||. See Figure 3-15.

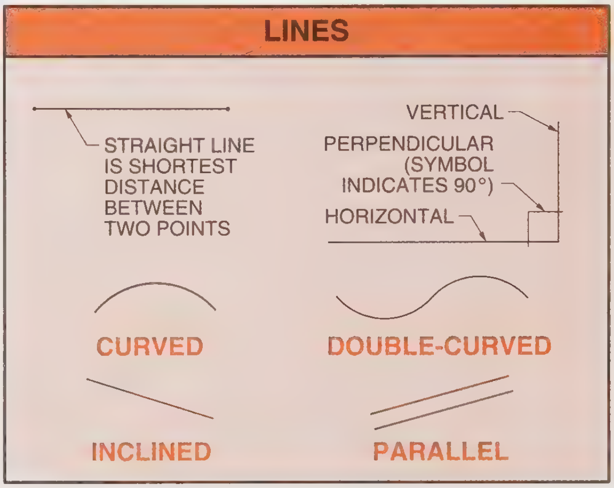


Figure 3-15. A straight line is the shortest distance between two points.

Angles. An *angle* is the intersection of two lines. The symbol for angle is ∠. Angles are measured in degrees, minutes, and seconds. The symbol for degrees is °. The symbol for minutes is ′. The symbol for seconds is ″. There are 360° in a circle. There are 60 minutes in one degree and 60 seconds in one minute. For example, an angle might contain 112°-30′-12″.

A *straight angle* contains 180°. A *right angle* contains 90°. An *acute angle* contains less than 90°. An *obtuse angle* contains more than 90°. *Complementary angles* equal 90°. *Supplementary angles* equal 180°. See Figure 3-16.

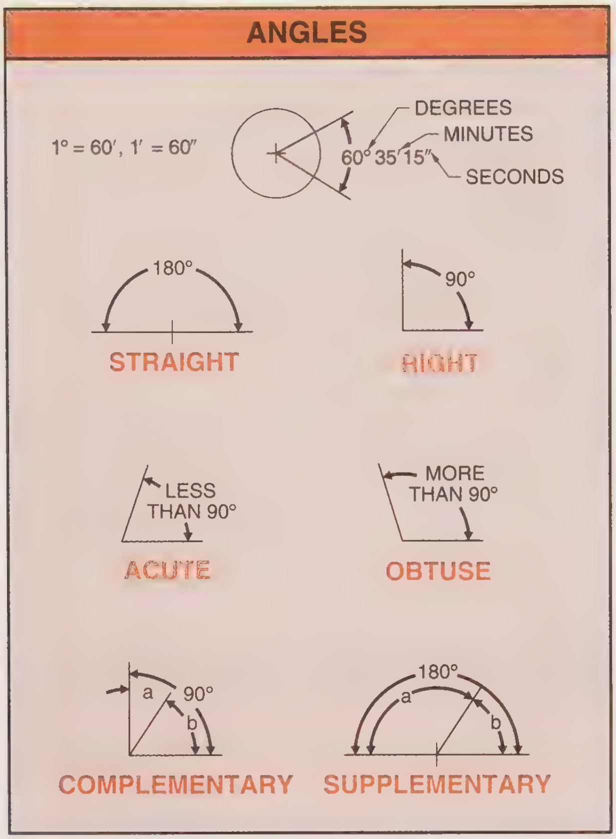


Figure 3-16. An angle is the intersection of two lines.

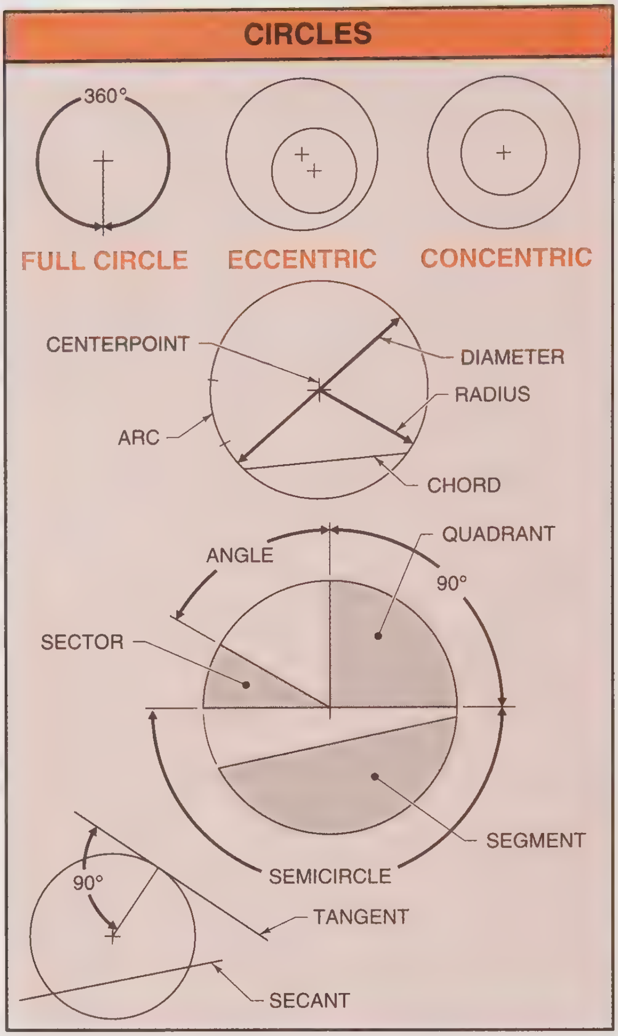


Figure 3-17. A circle is a plane figure generated around a centerpoint.

Circles

A *circle* is a plane figure generated around a centerpoint. All circles contain 360°. The *diameter* is the distance from circumference (outside) to circumference through the centerpoint. The *circumference* is 3.1416 times the diameter of a circle. The *radius* is one-half the length of the diameter. See Figure 3-17.

A *chord* is a line from circumference to circumference not through the centerpoint. An *arc* is a portion of the circumference. A *quadrant* is one-fourth of a circle. Quadrants have a right angle. A *sector* is a pie-shaped piece of a circle. A *segment* is the portion of a circle set off by a chord. A *semicircle* is one-half of a circle. Semicircles always contain 180°. *Concentric circles* have different diameters and the same centerpoint. *Eccentric circles* have different diameters and different centerpoints. A *tangent* is a straight line touching the circumference at only one point. It is 90° to the radius. A *secant* is a straight line touching the circumference at two points.

Triangles

A *triangle* is a three-sided polygon with three interior angles. The sum of the three angles of a triangle is always 180°. The sign (Δ) indicates a triangle. See Figure 3-18.

The *altitude* of a triangle is the perpendicular dimension from the vertex to the base. The *base* of a triangle is the side upon which the triangle stands. Any side can be taken as the base.

The angles of a triangle are named by uppercase letters. The sides of a triangle are named by lowercase letters. For example, a triangle may be named ΔABC and contain sides d, e, and f.

The different kinds of triangles are right triangles, isosceles triangles, equilateral triangles, and scalene triangles.

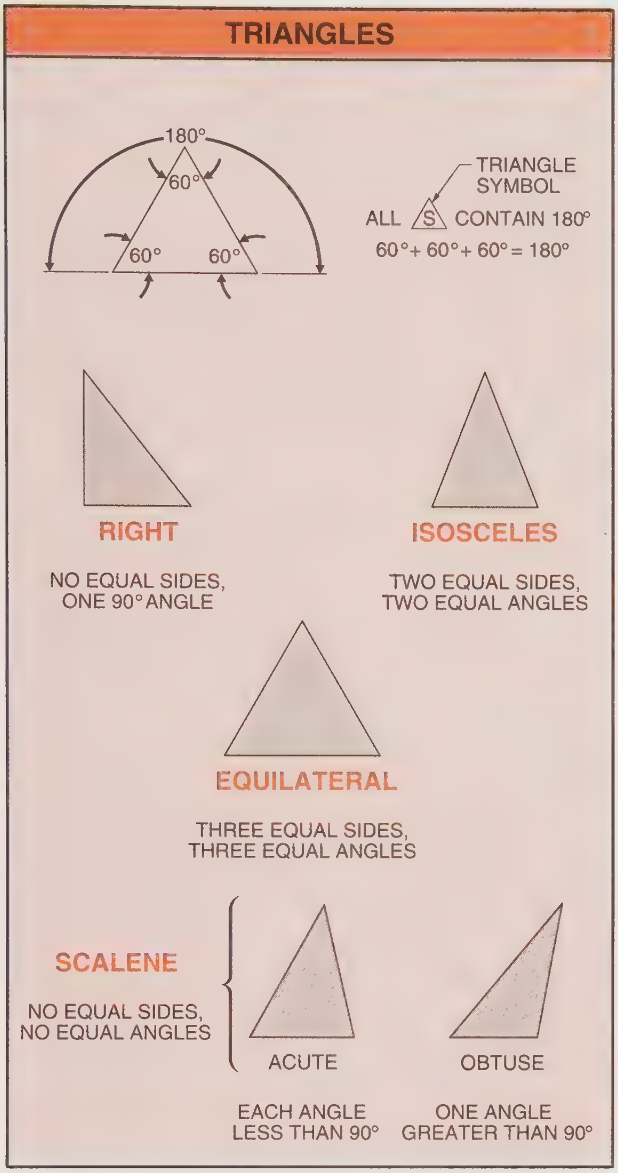


Figure 3-18. A triangle is a three-sided plane figure.

A *right triangle* is a triangle that contains one 90° angle and no equal sides. An *isosceles triangle* is a triangle that contains two equal angles and two equal sides.

An *equilateral triangle* is a triangle that has three equal angles and three equal sides. Each angle of an equilateral triangle is 60°.

A *scalene triangle* is a triangle that has no equal angles or equal sides. A scalene triangle may be acute or obtuse. An *acute triangle* is a scalene triangle with each angle less than 90°. An *obtuse triangle* is a scalene triangle with one angle greater than 90°.

Quadrilaterals

A *quadrilateral* is a four-sided polygon with four interior angles. The sum of the four angles of a quadrilateral is always 360°. The kinds of quadrilaterals are squares, rectangles, rhombuses, rhomboids, trapezoids, and trapeziums. See Figure 3-19.

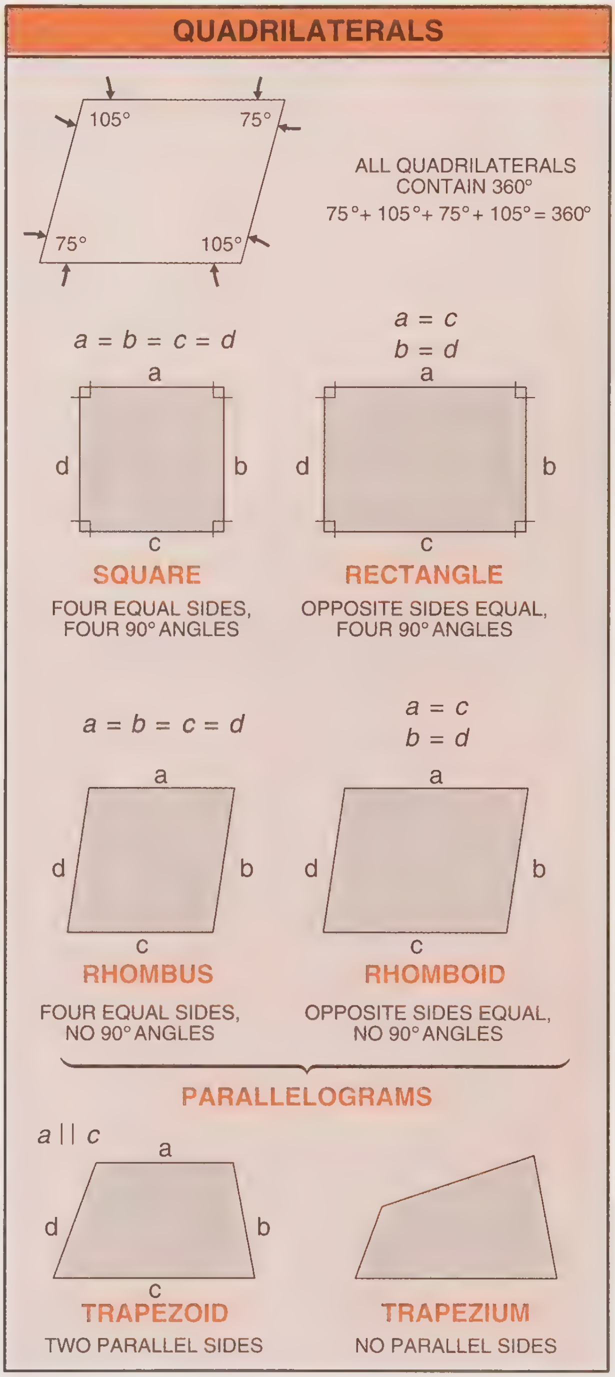


Figure 3-19. A quadrilateral is a four-sided plane figure.

A *square* is a quadrilateral with all sides equal and four 90° angles. A *rectangle* is a quadrilateral with opposite sides equal and four 90° angles. A *rhombus* is a quadrilateral with all sides equal and no 90° angles. A *rhomboid* is a quadrilateral with opposite sides equal and no 90° angles.

The square, rectangle, rhombus, and rhomboid are parallelograms. A *parallelogram* is a four-sided plane figure with opposite sides parallel and equal.

A *trapezoid* is a quadrilateral with two sides parallel. A *trapezium* is a quadrilateral with no sides parallel. Trapezoids and trapeziums are not parallelograms because all opposite sides are not parallel.

Polygons

A *polygon* is a many-sided plane figure. All polygons are bounded by straight lines. A *regular polygon* has equal sides and equal angles. An *irregular polygon* has unequal sides and unequal angles. Polygons are named according to their number of sides. For example, a triangle has three sides; a quadrilateral has four sides; a pentagon has five sides; a hexagon has six sides; a heptagon has seven sides; an octagon has eight sides; etc. See Figure 3-20.

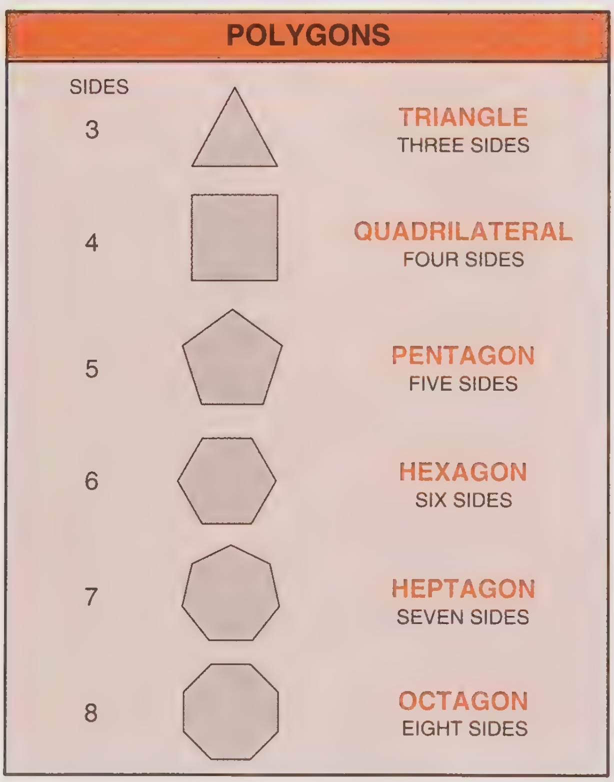


Figure 3-20. A polygon is a many-sided plane figure.

SOLIDS FIGURES

Polyhedra are solids bound by plane surfaces (faces). *Regular solids* (polyhedra) are solids with faces that are regular polygons (equal sides). *Irregular polyhedra* are solids with faces that are irregular polygons (unequal sides).

Solids have length, height, and depth. The five regular solids are the tetrahedron, hexahedron, octahedron, dodecahedron, and icosahedron. Other common solids are prisms, cylinders, pyramids, cones, and spheres. Less common solids include the torus and ellipsoid. See Figure 3-21.

Regular Solids

A *tetrahedron* is a regular solid of four triangles. A *hexahedron* is a regular solid of six squares. It is commonly referred to as a cube. An *octahedron* is a regular solid of eight triangles. A *dodecahedron* is a regular solid of twelve pentagons. An *icosahedron* is a regular solid of twenty triangles.

Prisms

A *prism* is a solid with two bases that are parallel and identical polygons. *Bases* are the ends of a prism. The three or more sides of a prism are parallelograms. See Figure 3-22. A prism can be triangular, rectangular, pentagonal, hexagonal, octagonal, etc. according to the shape of its bases.

Lateral faces are the sides of a prism. There are as many of these lateral faces as there are sides in one of the bases.

The *altitude* of a prism is the perpendicular distance between the two bases. When the bases are perpendicular to the faces, the altitude equals the edge of a lateral face.

A *right prism* is a prism with lateral faces perpendicular to the bases. An *oblique prism* is a prism with lateral faces not perpendicular to the bases.

A *parallelepiped* is a prism with bases that are parallelograms. A *right parallelepiped* is a prism with all edges perpendicular to the bases. A *rectangular parallelepiped* is a prism with bases and faces that are all rectangles.

Cylinders

A *cylinder* is a solid generated by a straight line (genatrix) moving in contact with a curve and remaining parallel to the axis and its previous position.

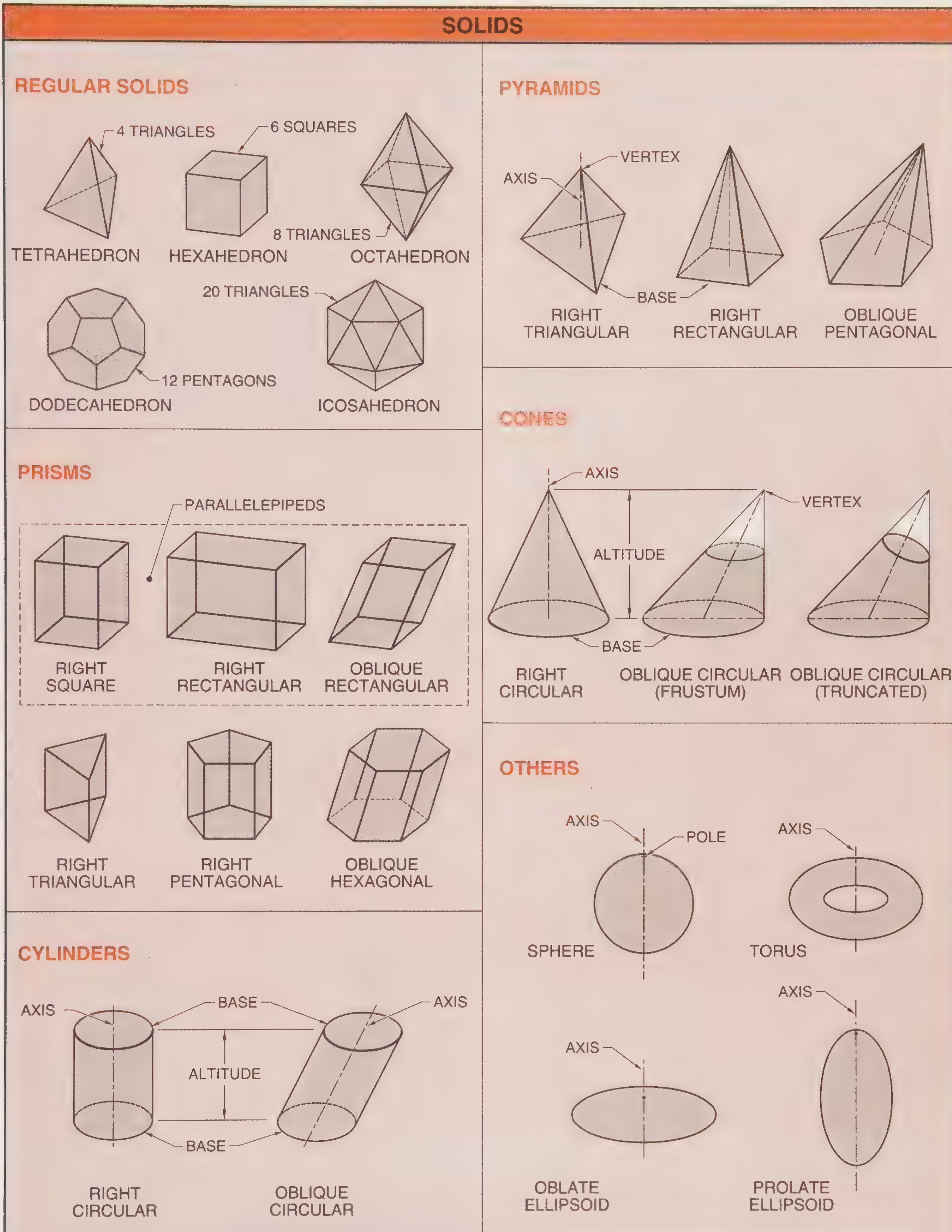


Figure 3-21. Solids have length, height, and depth.

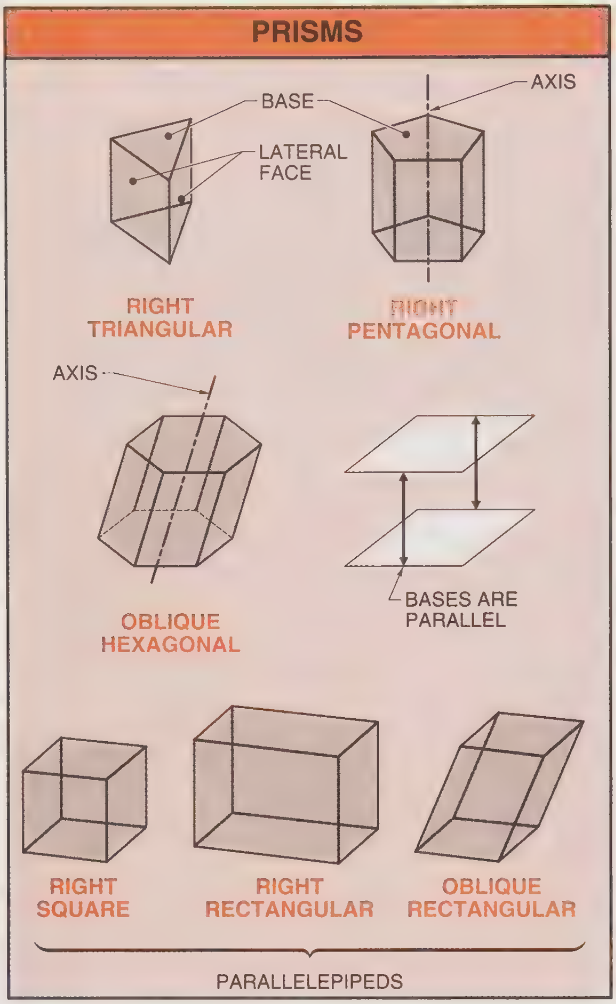


Figure 3-22. A prism is a solid with two bases that are parallel and identical polygons.

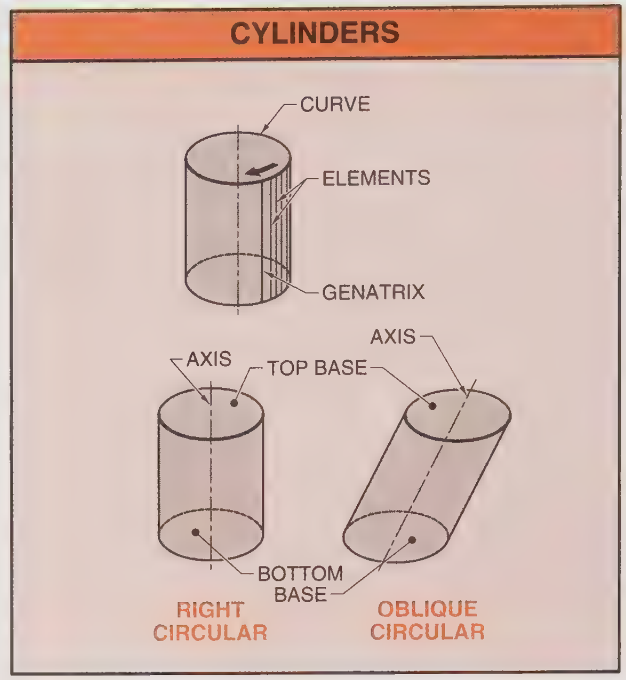


Figure 3-23. A cylinder is a solid generated by a straight line (genatrix) moving in contact with a curve and remaining parallel.

Each position of the genatrix forms an element of the cylinder.

A *right cylinder* is a cylinder with the axis perpendicular to the base. An *oblique cylinder* is a cylinder with the axis not perpendicular to the base. See Figure 3-23.

Pyramids

A *pyramid* is a solid with a base that is a polygon and sides that are triangles. The *vertex* is the common point of the triangular sides that forms the pyramid. See Figure 3-24.

The *altitude* of a pyramid is the perpendicular distance from the vertex to the base. Pyramids are named according to the kind of polygon forming the base, such as triangular, quadrangular, pentagonal, and hexagonal.

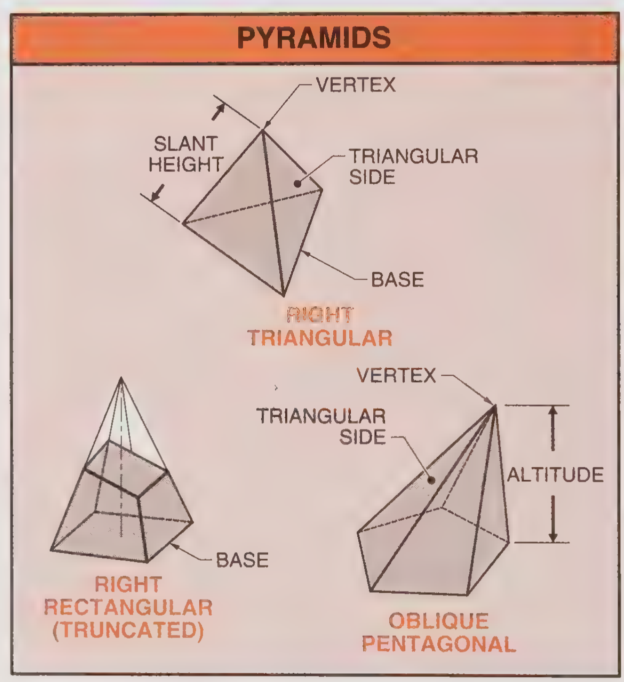


Figure 3-24. A pyramid is a solid with a base that is a polygon and sides that are triangles.

A *regular pyramid* has a base that is a regular polygon and a vertex that is perpendicular to the center of the base. The *slant height* is the

distance from the base to the vertex parallel to a side. It is the altitude of one of the triangles that forms the sides.

Cones

A *cone* is a solid generated by a straight line moving in contact with a curve and passing through the vertex. Cones have a circular base and a surface that tapers from the base to the vertex.

The altitude of a cone is the perpendicular distance from the vertex to the base. The slant height is the distance from the vertex to any point on the circumference of the base. See Figure 3-25.

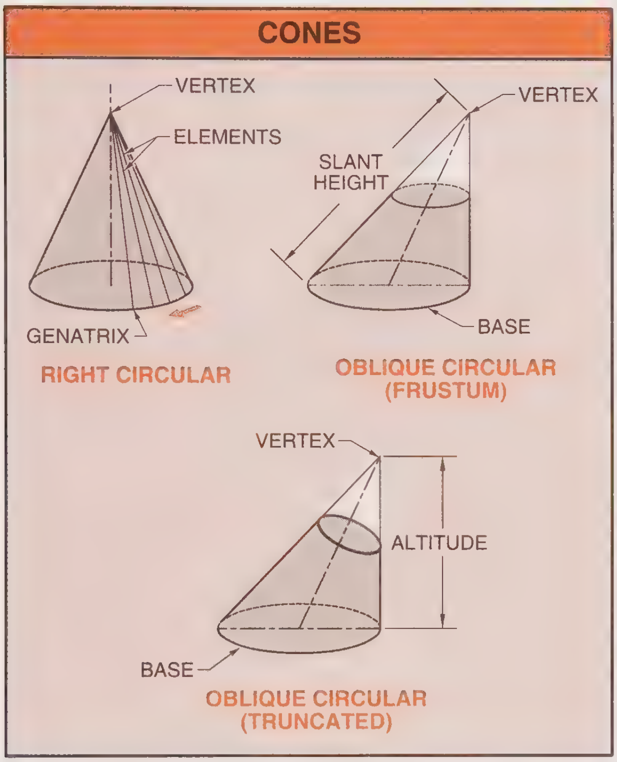


Figure 3-25. A cone is a solid generated by a straight line (genatrix) moving in contact with a circle and passing through the vertex.

Conic Sections. A *conic section* is a curve produced by a plane intersecting a right circular cone. A *right circular cone* is a cone with the axis at a 90° angle to the circular base. The four conic sections are the circle, ellipse, parabola, and hyperbola. See Figure 3-26.

A *circle* is a plane figure formed by a cutting plane perpendicular to the axis of a cone. An *ellipse* is a plane figure formed by a cutting plane oblique to the axis of a cone, but at a greater angle with the axis than with the elements of the cone.

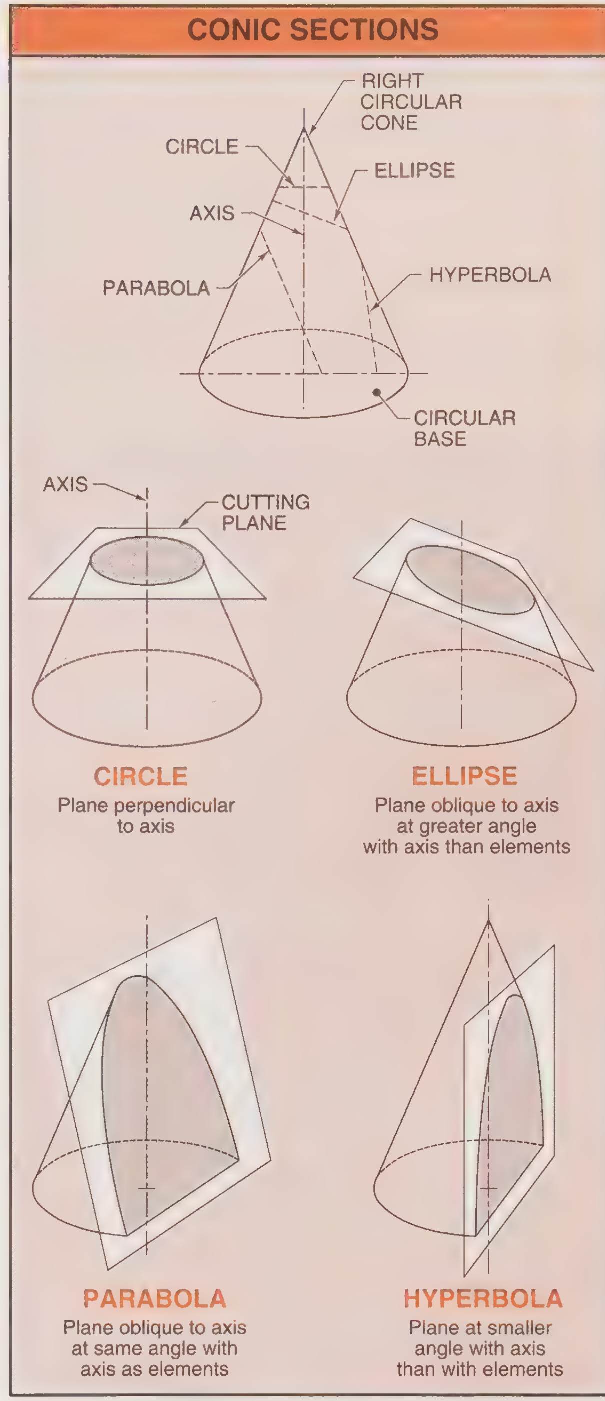


Figure 3-26. A conic section is a curve produced by a plane intersecting a right circular cone.

A *parabola* is a plane figure formed by a cutting plane oblique to the axis and parallel to the elements of the cone. A *hyperbola* is a plane figure formed by a cutting plane that has a smaller angle with the axis than with the elements of the cone.

Frustums. A *frustum* of a pyramid or cone is the remaining portion of a pyramid or cone with a cutting plane passed parallel to the base. A truncated pyramid or cone is the remaining portion of a pyramid or cone with the cutting plane passed not parallel to the base. See Figure 3-27.

Spheres

A *sphere* is a solid generated by a circle revolving about one of its axes. All points on the surface are an equal distance from the center of the sphere. See Figure 3-28.

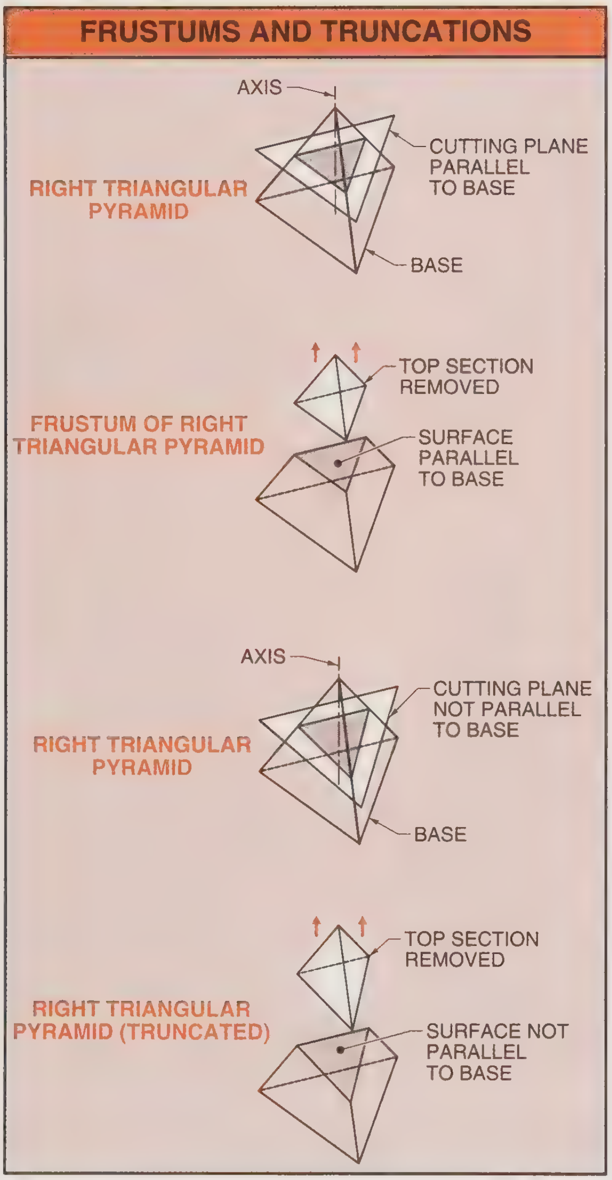


Figure 3-27. A frustum is the remaining piece of a pyramid or cone with a cutting plane passed parallel to the base.

A *great circle* is the circle formed by passing a cutting plane through the center of a sphere. A *small circle* is the circle formed by passing a cutting plane through a sphere but not through the center. The circumference of a sphere is equal to the circumference of a great circle.

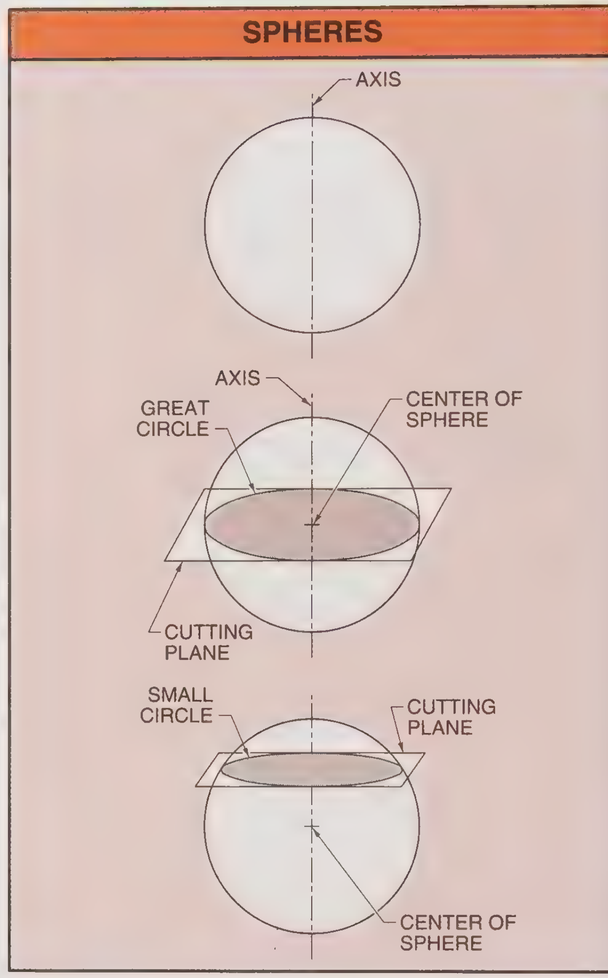


Figure 3-28. A sphere is a solid generated by a circle revolving about the axis.

MEASUREMENT TOOLS

Machine shop measurement tools are precision measuring instruments capable of minute measurements. Common machine shop measurement tools include rules, squares, protractors, micrometers, calipers, gauges, and indicators. Machine shop measurement tools are commercially available in English and Metric systems in a variety of sizes. Their output may be conventional, digitized, or computerized.

Rules

Rules are used for linear measurement. See Figure 3-29. The most common rules in the machine shop are the bench and steel rules. Both edges of both sides are graduated.

The metric steel rule is made of tempered steel with deeply etched graduations. The metric equivalent rule is made of aluminum. It contains metric-english equivalents for lines, weights, and liquids.

The pocket rule is made of stainless steel. It has a pocket clip which is also used as a depth gauge. The back side contains decimal equivalents.

Squares

Squares are used to layout and check 90° (right) angles. See Figure 3-30. The try and meter square has ⅛″ graduations on both sides. The mitered handle is used to layout and check 45° angles.

The engineer's square has no graduations. It is used for machine set-up and right angles.

The combination square is available with 6″ or 12″ blades, it also serves as a depth gauge. A center head is used to locate centers for turned stock. The protractor head allows the combination square blade to be used in measuring and laying out angles.

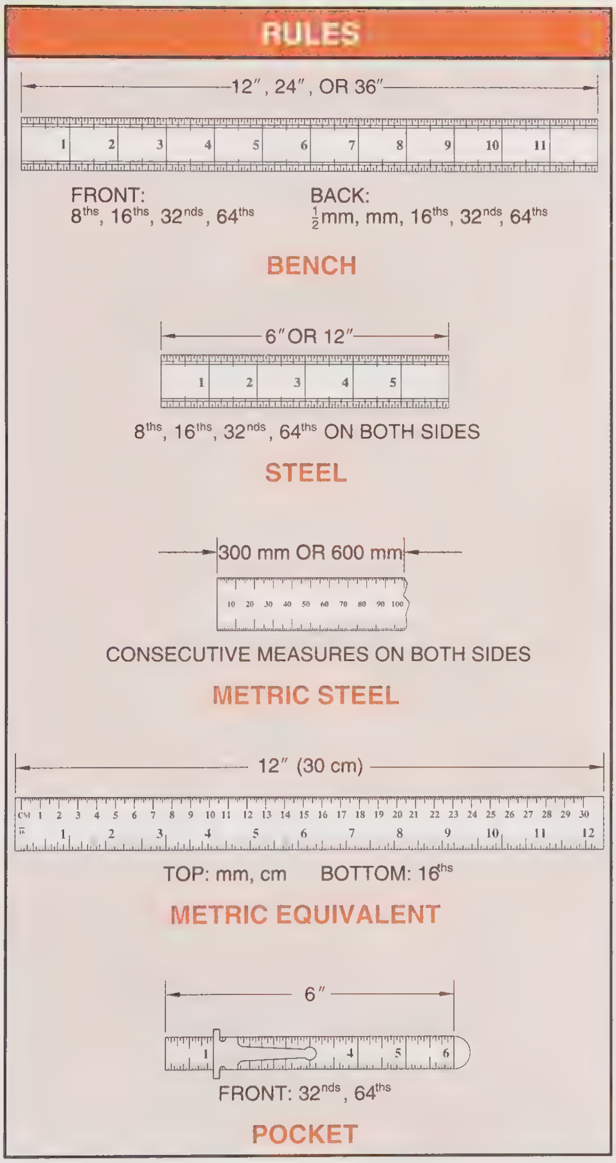


Figure 3-29. Rules are used for linear measurement.

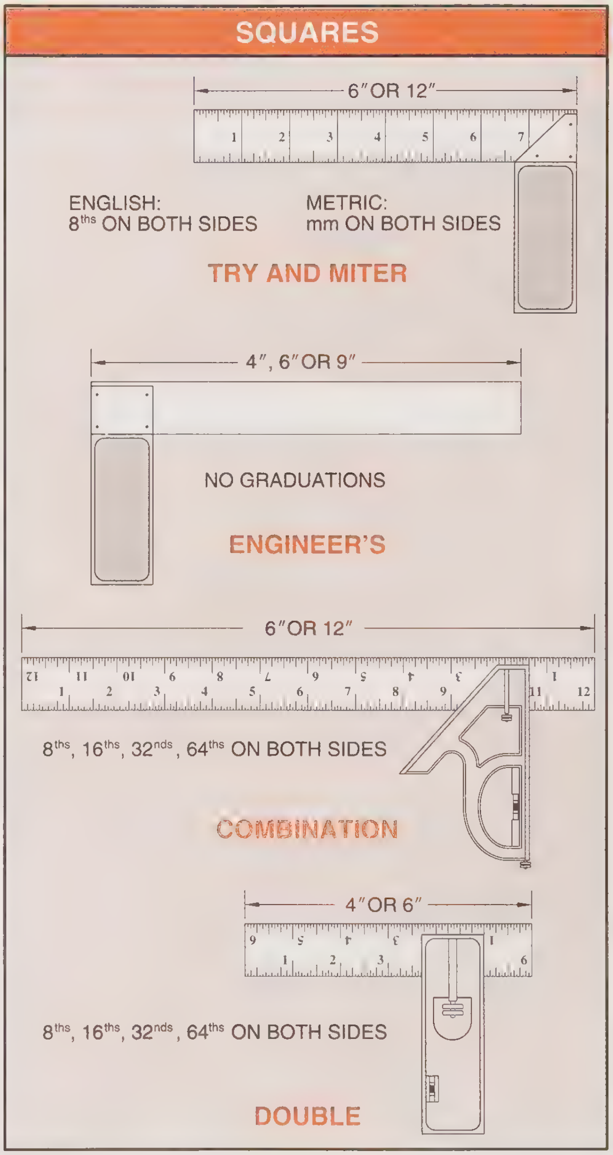


Figure 3-30. Squares are used for 90° angles.

Protractors

Protractors are used for measuring and laying out angles. See Figure 3-31. The base line (0°-180°) is placed on one leg of an angle, and with the center point as the vertex, the desired angle is measured or laid out. The reversible vernier protractor provides more precise measurement than a regular protractor.

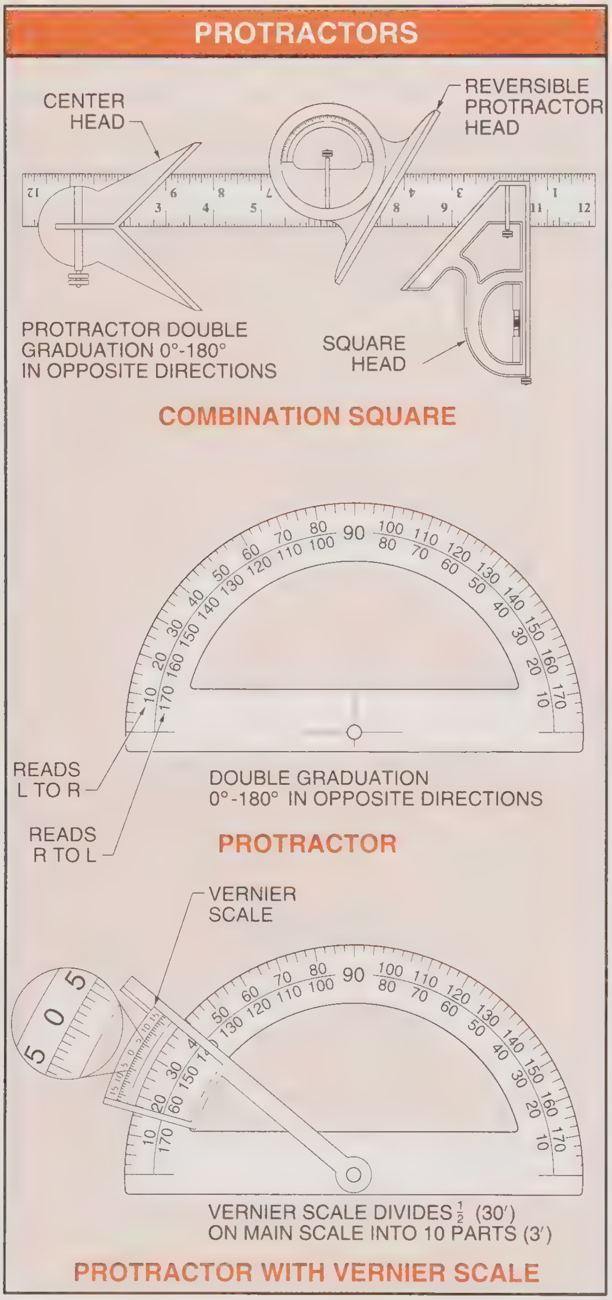
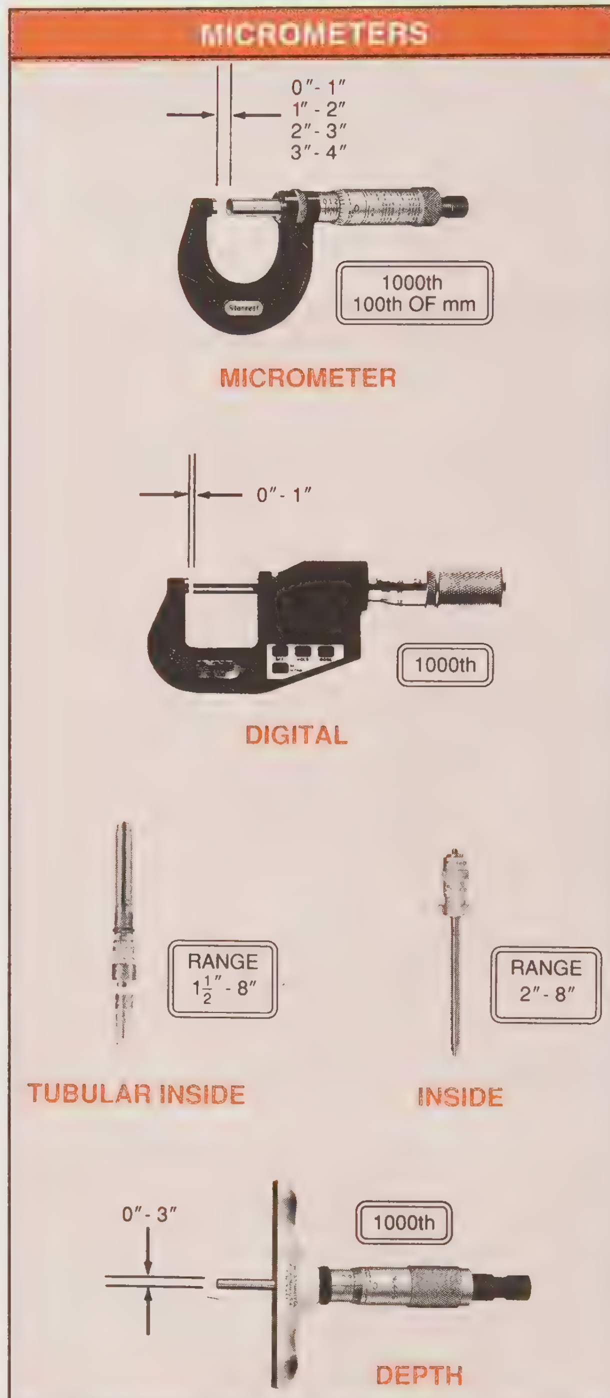


Figure 3-31. Protractors are used for measuring and laying out angles.

Micrometers

Micrometers are used to measure diameters and thicknesses. See Figure 3-32. Tubular micrometers are used to measure inside diameters. Depth micrometers are used to measure the depth of holes.

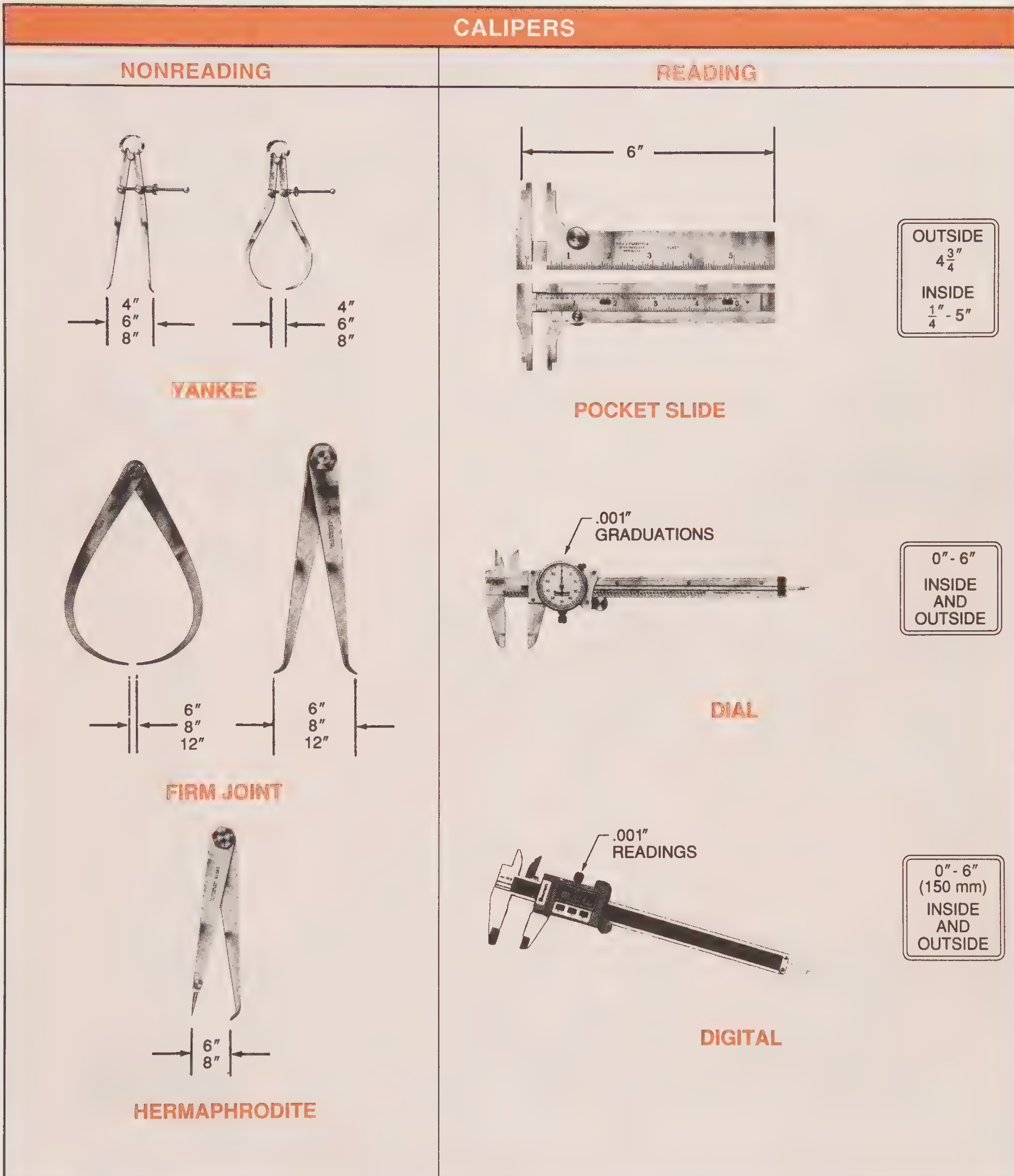


The L. S. Starrett Company

Figure 3-32. Micrometers are used to measure diameter and thicknesses.

Calipers

Calipers are instruments used to measure inside and outside distances and diameters. See Figure 3-33. Nonreading calipers are commonly used to check and transfer dimensions. Reading calipers are used for more precise work.Calipers should never be forced onto the work. Measurements should be made with light contact.

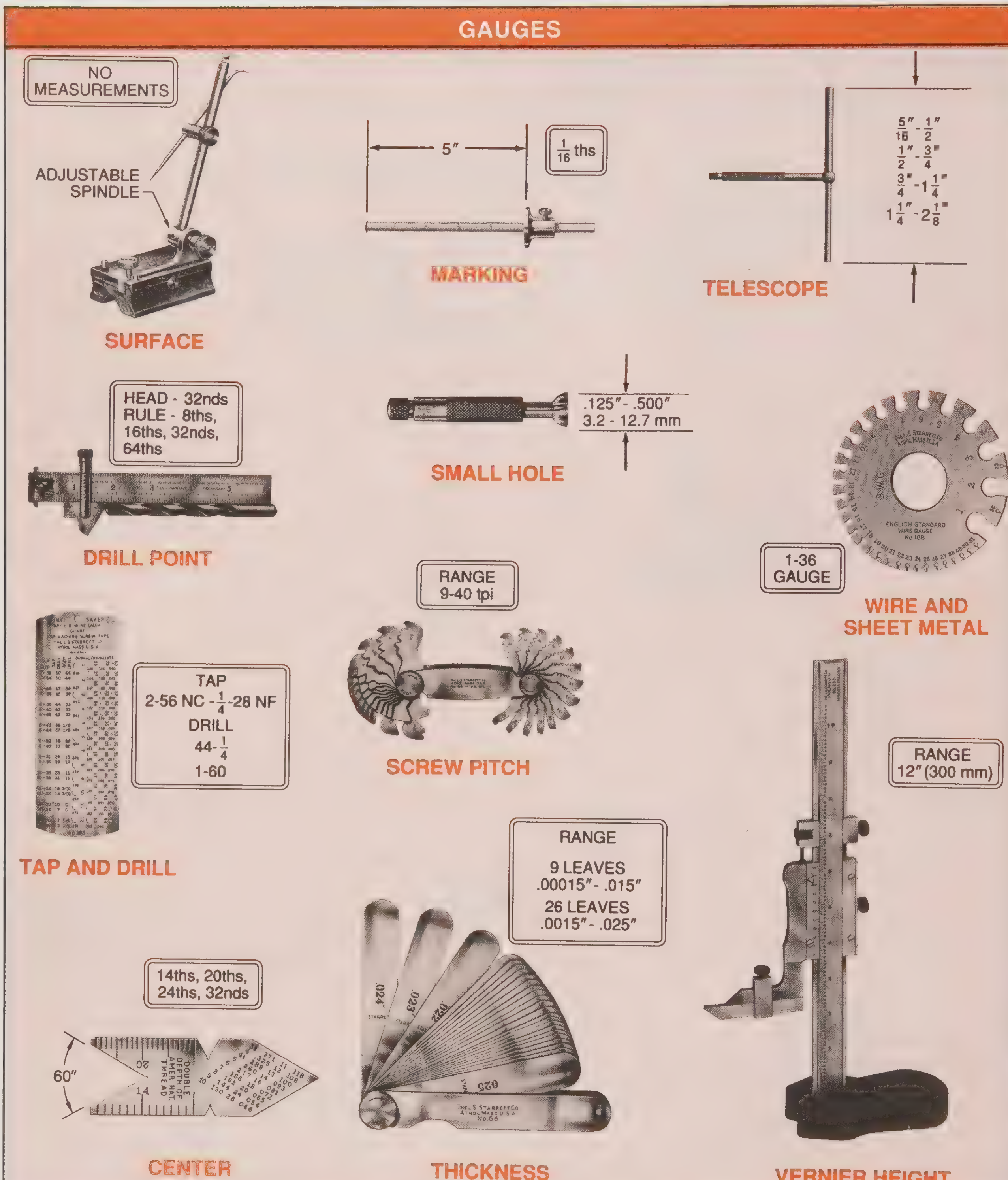


The L. S. Starrett Company

Figure 3-33. Calipers are used to measure inside and outside distances and diameters.

Gauges

Gauges are used to check standard sizes and angles. See Figure 3-34. They may also be used to transfer dimensions. Standard gauges of tap and drill sizes, wire and sheet metal sizes, and screw pitches are commonly used in the machine shop. Gauges should never be forced onto the work. Measurements should be made with light contact.

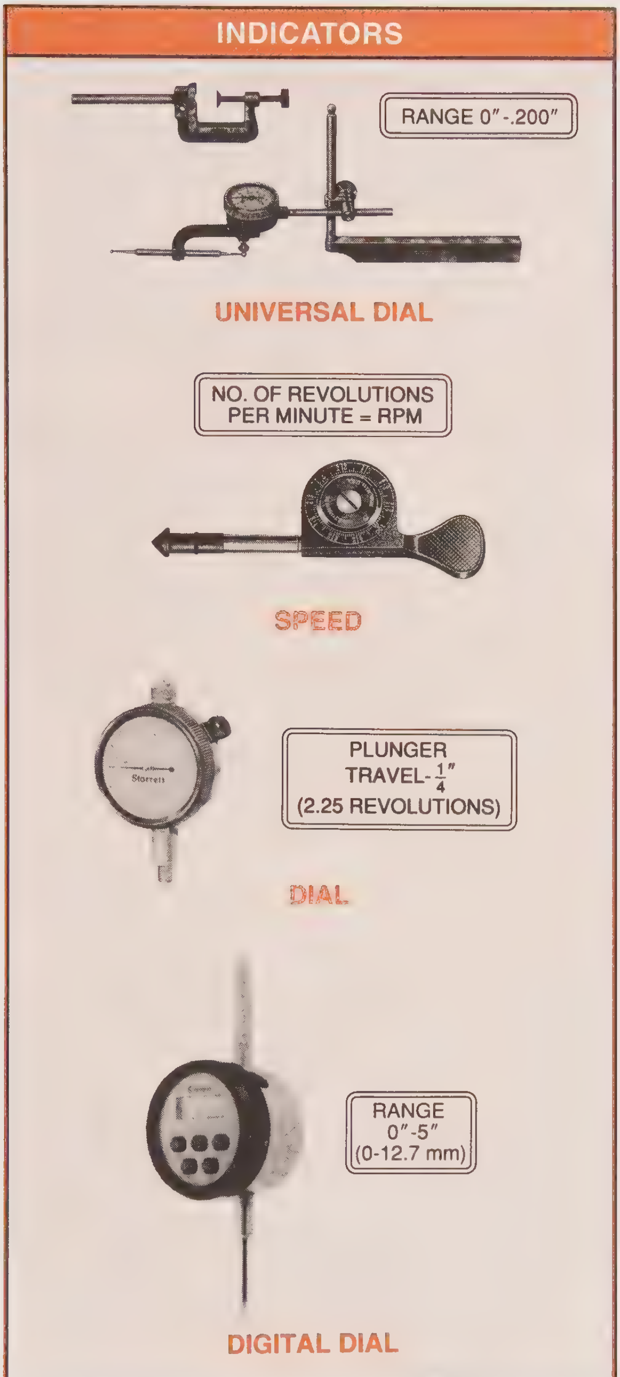


The L. S. Starrett Company

Figure 3-34. Gauges are used to check standard sizes and angles.

Indicators

Indicators are used to measure variations from fixed points. See Figure 3-35. Typical variations include out-of-round parts, and height or thickness differential. Speed indicators measure rpm of turning parts.



The L. S. Starrett Company

Figure 3-35. Indicators are used to measure variations from fixed points.

BASIC MATH FORMULAS

An *equation* is a means of showing that two numbers or two groups of numbers are equal to the same amount. For example, a baker has two pies of the same size. Pie A is cut into six equal pieces, and Pie B is cut into eight equal pieces. One customer buys three pieces of Pie A, and another customer buys four pieces of Pie B. The customers have bought the same amount of pie because $\frac{3}{6} = \frac{1}{2}$ and $\frac{4}{8} = \frac{1}{2}$. All equations must balance, and as $\frac{3}{6}$ and $\frac{4}{8}$ each equal $\frac{1}{2}$, $\frac{3}{6} = \frac{4}{8}$ is an equation.

A *formula* is a mathematical equation which contains a fact, rule, or principle. Letters are used in formulas to represent values (amount). In the common electrical formula, $I = VA/V$, the I represents ampacity (denoted A), the VA represents wattage or volt amps (denoted VA), and the V represents voltage (denoted V). If any two of these values are known, the other value can be found by rearranging the formula. See Figure 3-36.

Ampacity is found by applying the formula:

$$I = \frac{VA}{V}$$

where

I = ampacity (in A)

VA = wattage or volt amps (in VA)

V = voltage (in V)

For example, what is the ampacity of a 120 V electric circuit with 2400 watts?

$$I = \frac{VA}{V}$$

$$I = \frac{2400}{120}$$

$$I = \mathbf{20\ A}$$

Voltage is found by applying the formula:

$$V = \frac{VA}{I}$$

For example, what is the voltage of a 15 A circuit with 1800 VA?

$$V = \frac{VA}{I}$$

$$V = \frac{1800}{15}$$

$$V = \mathbf{120\ V}$$

Wattage is found by applying the formula:

$VA = I \times V$

For example, what is the volt amps of a 120 V, 30 A circuit?

$VA = I \times V$

$VA = 30 \times 120$

$VA =$ **3600 VA**

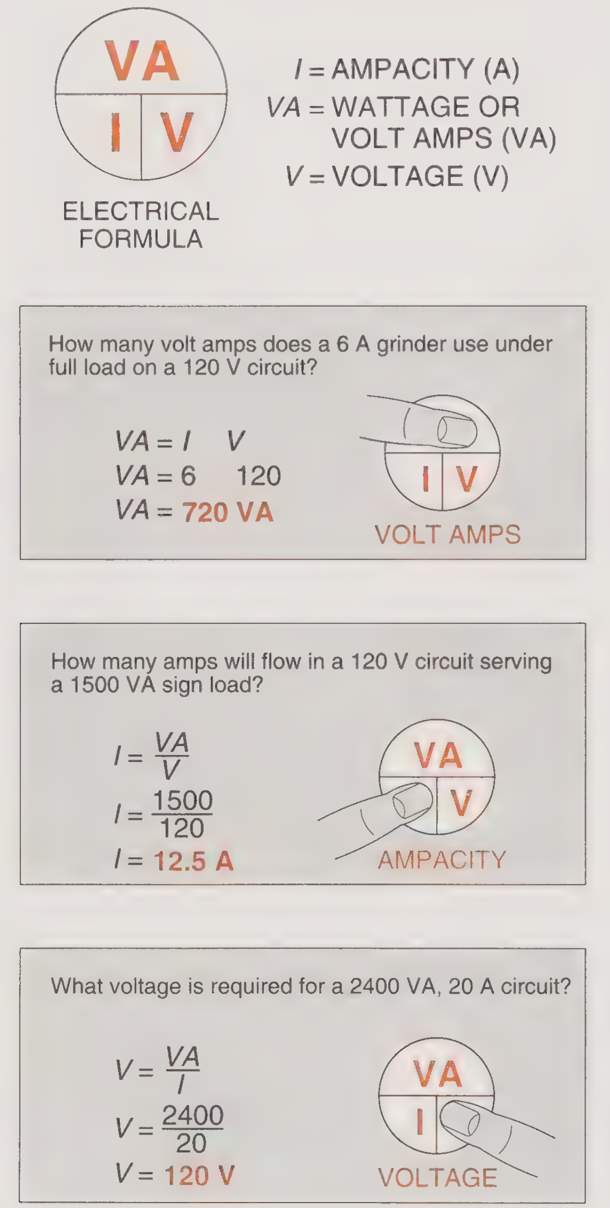


Figure 3-36. When two values of a formula are known, the third value can be found.

Greek Letters

The letters of the Greek alphabet are frequently used in math formulas. For example, the Greek letter Pi represents 3.1416, the circumference of a circle. Pi is written as π. Uppercase and lowercase letters are used in the Greek alphabet. See Figure 3-37.

GREEK LETTERS					
Αα	ALPHA	Ιι	IOTA	Ρρ	RHO
Ββ	BETA	Κκ	KAPPA	Σσ	SIGMA
Γγ	GAMMA	Λλ	LAMBDA	Ττ	TAU
Δδ	DELTA	Μμ	ZETA	Υυ	UPSILON
Εε	EPSILON	Νν	NU	Φφ	PHI
Ζζ	ZETA	Ξε	XI	Χχ	CHI
Ηη	ETA	Οο	OMICRON	Ψψ	PSI
Θθ	THETA	Ππ	PI	Ωω	OMEGA

Figure 3-37. The letters of the Greek alphabet are frequently used in math formulas.

Common Formulas

In the metal trades, common formulas related to plane and solid figures are used when laying out jobs. For example, a welder may be required to lay out and build a cylindrical tank to hold a specified number of gallons of liquid. By applying the volume formula for cylinders, the welder can determine the size of the cylindrical tank.

Area. *Area* is the number of unit squares equal to the surface of an object. For example, a standard size piece of plywood contains 32 sq ft ($4 \times 8 =$ 32 sq ft). Area is expressed in square inches, square feet, and other units of measure. A *square inch* measures $1'' \times 1''$ or its equivalent. A *square foot* contains 144 sq in. ($12'' \times 12'' = 144$ sq in.). The area of any plane figure can be determined by applying the proper formula. See Figure 3-38.

Circumference of a Circle (Diameter). When the diameter is known, the circumference of a circle is found by applying the formula:

$C = \pi D$

where

C = circumference

π = 3.1416

D = diameter

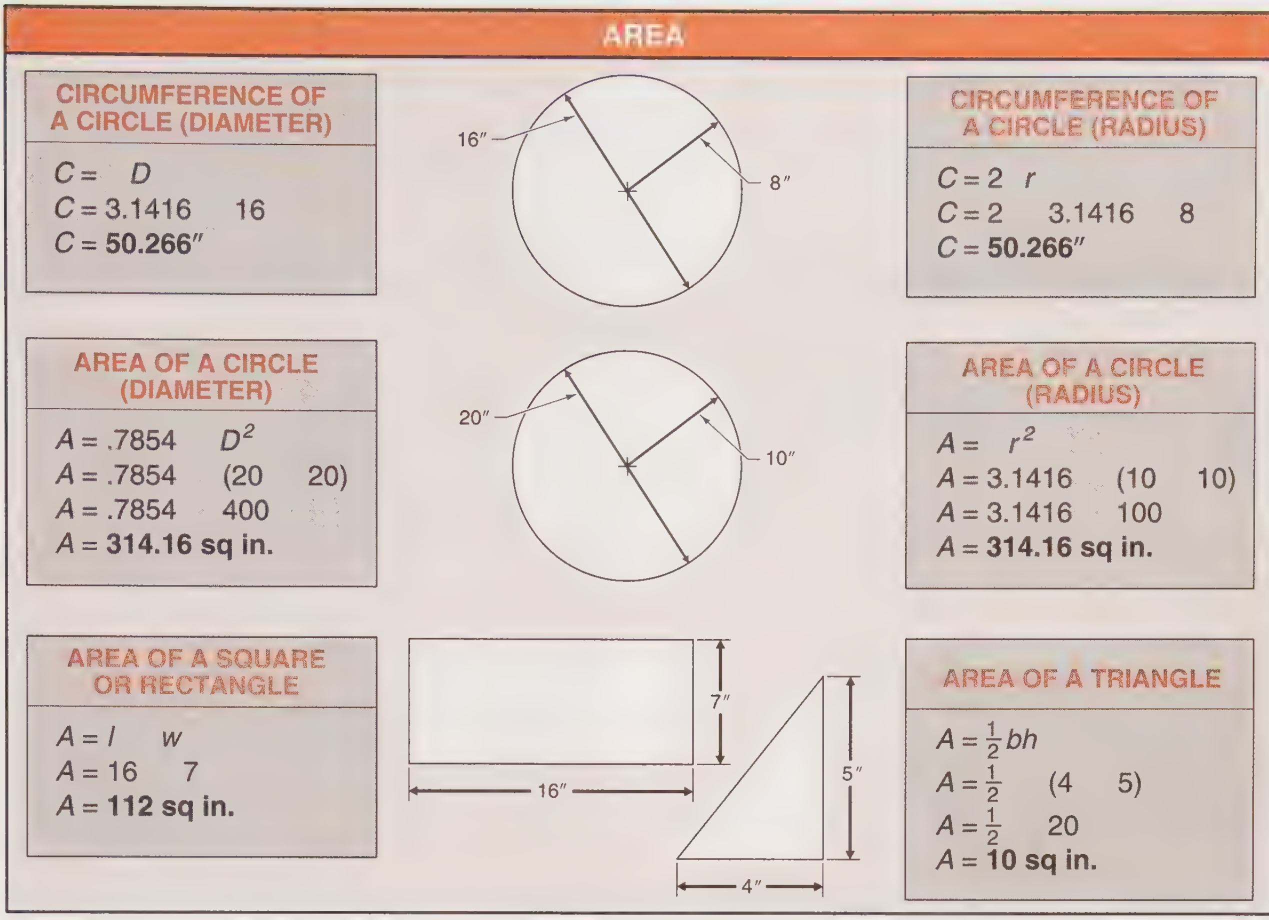


Figure 3-38. Area is the number of unit squares equal to the surface of an object.

For example, what is the circumference of a 20″ diameter circle?

$C = \pi D$

$C = 3.1416 \times 20$

$C = \mathbf{62.832''}$

Circumference of a Circle (Radius). When the radius is known, the circumference of a circle is found by applying the formula:

$C = 2\pi r$

where

C = circumference

2 = constant

$\pi = 3.1416$

r = radius

For example, what is the circumference of a 10″ radius circle?

$C = 2\pi r$

$C = 2 \times 3.1416 \times 10$

$C = \mathbf{62.832''}$

Area of a Circle (Diameter). When the diameter is known, the area of a circle is found by applying the formula:

$A = .7854 \times D^2$

where

A = area

.7854 = constant

D^2 = diameter squared

For example, what is the area of a 28″ diameter circle?

$A = .7854 \times D^2$

$A = .7854 \times (28 \times 28)$

$A = .7854 \times 784$

$A = \mathbf{615.754 \text{ sq in.}}$

Area of a Circle (Radius). When the radius is known, the area of a circle is found by applying the formula:

$A = \pi r^2$

where

A = area
π = 3.1416
r^2 = radius squared

For example, what is the area of a 14″ radius circle?

$A = \pi r^2$
$A = 3.1416 \times (14 \times 14)$
$A = 3.1416 \times 196$
$A =$ **615.754 sq in.**

Area of a Square or Rectangle. The area of a square or the area of a rectangle is found by applying the formula:

$A = l \times w$
where
A = area
l = length
w = width

For example, what is the area of a 22′-0″ × 16′-0″ storage room?

$A = l \times w$
$A = 22 \times 16$
$A =$ **352 sq ft**

Area of a Triangle. The area of a triangle is found by applying the formula:

$A = \frac{1}{2}bh$
where
A = area
$\frac{1}{2}$ = constant
b = base
h = height

For example, what is the area of a triangle with a 10″ base and a 12″ height?

$A = \frac{1}{2}bh$
$A = \frac{1}{2} \times (10 \times 12)$
$A = \frac{1}{2} \times 120$
$A =$ **60 sq in.**

Pythagorean Theorem. The *Pythagorean Theorem* states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides. The *hypotenuse* is the side of a right triangle opposite the right angle. Because a right triangle can have a 3-4-5 relationship, it is often used in laying out right angles and checking corners for squareness. See Figure 3-39.

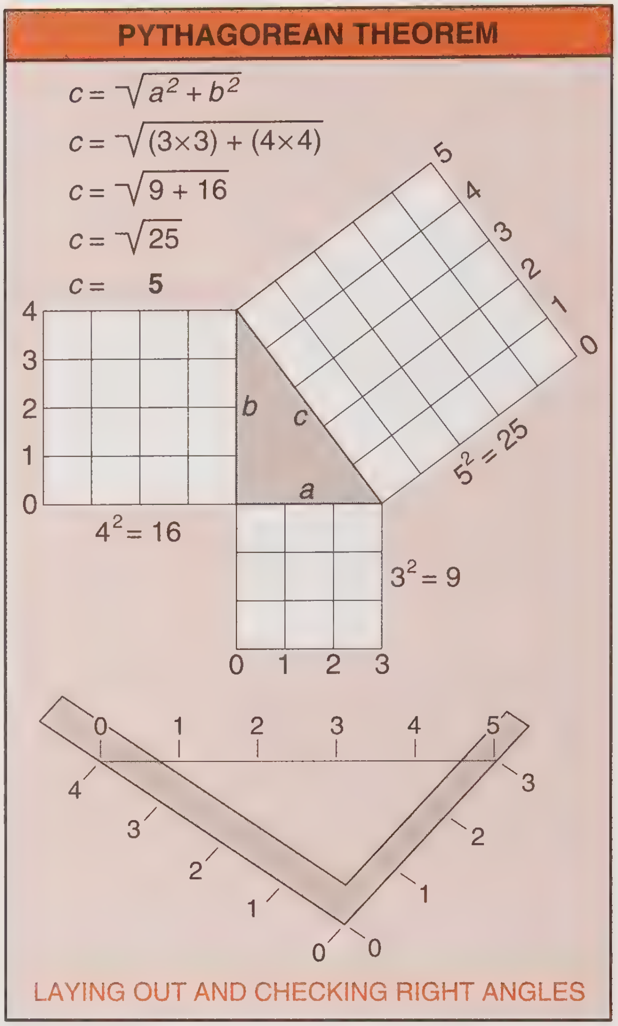


Figure 3-39. The square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides of the triangle.

The length of the hypotenuse of a right triangle is found by applying the formula:

$c = \sqrt{a^2 + b^2}$
where
c = length of hypotenuse
a^2 = length of one side squared
b^2 = length of other side squared

For example, what is the length of the hypotenuse of a triangle having sides of 3′ and 4′?

$c = \sqrt{a^2 + b^2}$
$c = \sqrt{(3 \times 3) + (4 \times 4)}$
$c = \sqrt{9 + 16}$
$c = \sqrt{25}$
$c =$ **5′**

Volume. *Volume* is the three-dimensional size of an object measured in cubic units. For example, the volume of a standard size concrete block is 1024 cu in. (8 × 8 × 16 = 1024 cu in.). Volume is expressed in cubic inches, cubic feet, cubic yards and other units of measure. A *cubic inch* measures 1″ × 1″ × 1″ or its equivalent. A *cubic foot* contains 1728 cu in. (12″ × 12″ × 12″ = 1728 cu in.). A cubic yard contains 27 cu ft (3′ × 3′ × 3′ = 27 cu ft). The volume of a solid figure can be determined by applying the proper formula. See Figure 3-40.

VOLUME

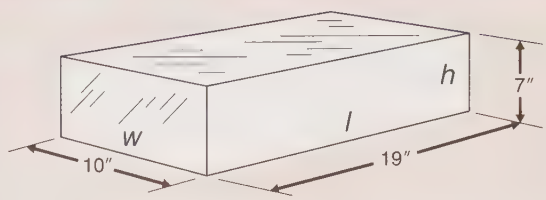
VOLUME OF A RECTANGULAR SOLID

$V = l \times w \times h$

$V = 19 \times 10 \times 7$

$V = 1330$ sq in.

$V = \frac{1330}{144} =$ **9.236 sq ft**



VOLUME OF A CYLINDER (DIAMETER)

$V = .7854 \times D^2 \times h$

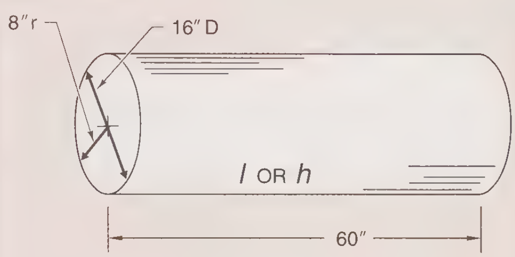
$V = .7854 \times (16 \times 16) \times 60$

$V = .7854 \times 256 \times 60$

$V = 12{,}063.744$ cu in.

$V = \frac{12{,}063.744}{1728}$

$V =$ **$6.981\overline{3}$ cu ft**



VOLUME OF A CYLINDER (RADIUS)

$V = r^2 \times l$

$V = 3.1416 \times (8 \times 8) \times 60$

$V = 3.1416 \times 64 \times 60$

$V = 12{,}063.744$ cu in.

$V = \frac{12{,}063.744}{1728}$

$V =$ **$6.981\overline{3}$ cu ft**

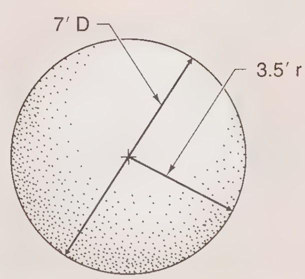
VOLUME OF A SPHERE (DIAMETER)

$V = \frac{\pi D^3}{6}$

$V = \frac{3.1416 \times 7^3}{6}$

$V = \frac{3.1416 \times 343}{6}$

$V =$ **179.5948 cu ft**



VOLUME OF A SPHERE (RADIUS)

$V = \frac{4\pi r^3}{3}$

$V = \frac{4 \times 3.1416 \times 3.5^3}{3}$

$V = \frac{4 \times 3.1416 \times 42.875}{3}$

$V =$ **179.5948 cu ft**

VOLUME OF A CONE

1. Solve for area of base	2. Solve for volume
$A_b = .7854 \times D^2$	$V = \frac{A_b a}{3}$
$A_b = .7854 \times (3.25 \times 3.25)$	$V = \frac{8.2958 \times 5}{3}$
$A_b = .7854 \times 10.5625$	$V = \frac{41.479}{3}$
$A_b =$ **8.2958 sq ft**	$V =$ **13.8263 cu ft**

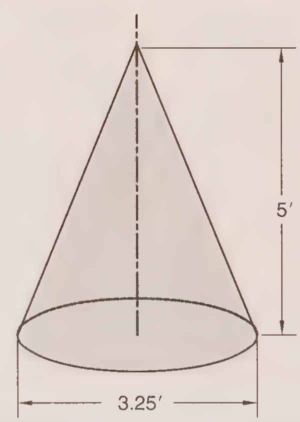


Figure 3-40. Volume is the three-dimensional size of an object.

Volume of a Rectangular Solid. The volume of a rectangular solid is found by applying the formula:

$V = l \times w \times h$

where

V = volume

l = length

w = width

h = height

Volume of a Cylinder (Diameter). When the diameter is known, the volume of a cylinder is found by applying the formula:

$V = .7854 \times D^2 \times h$

where

V = volume

.7854 = constant

D^2 = diameter squared

h = height

Volume of a Cylinder (Radius). When the radius is known, the volume of a cylinder is found by applying the formula:

$V = \pi r^2 \times l$

where

V = volume

π = 3.1416

r^2 = radius squared

l = length

Volume of a Sphere (Diameter). When the diameter is known, the volume of a sphere is found by applying the formula:

$$V = \frac{\pi D^3}{6}$$

where

V = volume

π = 3.1416

D^3 = diameter cubed

6 = constant

Volume of a Sphere (Radius). When the radius is known, the volume of a sphere is found by applying the formula:

$$V = \frac{4\pi r^3}{3}$$

where

V = volume

4 = constant

π = 3.1416

r^3 = radius cubed

3 = constant

Volume of a Cone. The volume of a cone is found by first solving for the area of the base and then solving for volume. The area of the base is found by applying the formula:

$A_b = .7854 \times D^2$

where

A_b = area of base

.7854 = constant

D^2 = diameter squared

The volume of the cone is then found by applying the formula:

$$V = \frac{A_b a}{3}$$

where

V = volume

A_b = area of base

a = altitude

3 = constant

Review Questions

Name ______________________________ Date ______________

True-False

T F 1. Arabic numerals are expressed by ten digits.

T F 2. Odd numbers cannot be divided by 2 an exact number of times.

T F 3. A mixed number has a numerator larger than the denominator.

T F 4. An improper fraction can be changed to a mixed number.

T F 5. Fractions are divided horizontally.

T F 6. The United States monetary system is based on Roman numerals.

T F 7. More places written in a decimal number indicate a higher degree of accuracy.

T F 8. Any number multiplied by a zero equals that number.

T F 9. To check division, multiply the sum by the quotient.

T F 10. The decimal point is the period in a decimal number.

T F 11. A circle is a plane figure.

T F 12. All plane figures are composed of lines drawn at various angles or with arcs.

T F 13. A vertical line is the shortest distance between two points.

T F 14. Parallel lines may vary in length and distance apart.

T F 15. Angles are measured in degrees, minutes, and seconds.

T F 16. A trapezoid is also a parallelogram.

T F 17. A scalene triangle has two equal sides and two equal angles.

T F 18. An octagon is a plane figure with six sides.

T F 19. The hypotenuse of a right triangle is the side opposite the right angle.

T F 20. A cubic foot contains 1278 cu in.

Completion

__________ 1. A(n) __________ number is any number that has no fractional or decimal parts.

__________ 2. A(n) __________ number is any number that can be divided by 2 an exact number of times.

______ 3. The ______ numeral system is the most commonly used numeral system in the United States.

______ 4. ______ are groups of three digits separated by a comma.

______ 5. ______ is the process of uniting two or more numbers to make one number.

______ 6. ______ is the opposite of addition.

______ 7. A(n) ______ or decimal is one part of a whole number.

______ 8. The ______ shows into how many parts a whole number has been divided.

______ 9. A(n) ______ is a fraction with a denominator of 10, 100, 1000, etc.

______ 10. The smallest whole number is ______.

Matching — Math

______ 1. Minuend

______ 2. Remainder

______ 3. Multiplier

______ 4. Divisor

______ 5. Sum

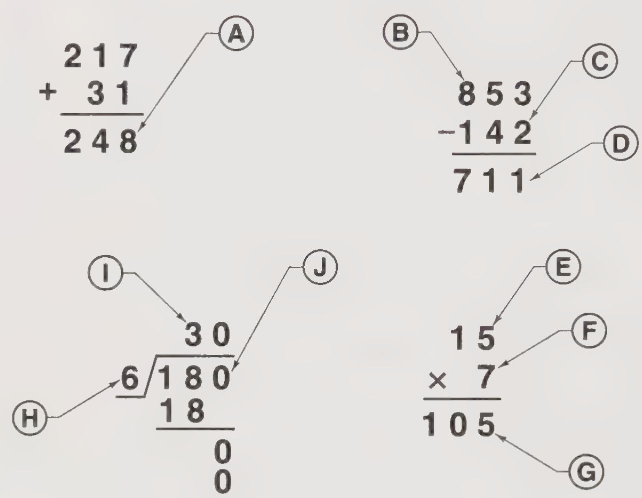
______ 6. Dividend

______ 7. Quotient

______ 8. Subtrahend

______ 9. Product

______ 10. Multiplicand



Multiple Choice

______ 1. ______ numbers are numbers that can be divided an exact number of times only by themselves and the number 1.

A. Proper
B. Period
C. Product
D. Prime

______ 2. The most common operation in mathematics is ______.

A. addition
B. subtraction
C. multiplication
D. division

______ 3. A(n) ______ fraction has a denominator larger than its numerator.

A. proper
B. improper
C. mixed
D. neither A, B, nor C

_____ **4.** The numerator is the _________-hand number of a fraction.

A. lower right
B. lower left
C. upper right
D. upper left

_____ **5.** Fractional parts of an inch are always expressed in their _________ common denominator.

A. highest
B. most
C. lowest
D. neither A, B, nor C

_____ **6.** Two numbers to the right of the decimal point indicate _________.

A. tenths
B. hundredths
C. thousandths
D. neither A, B, nor C

_____ **7.** A superscript rule placed over a Roman numeral letter increases the letter's value _________ times.

A. 10
B. 100
C. 1000
D. 10,000

_____ **8.** The larger number is commonly used as the _________ when the units being multiplied are the same.

A. multiplier
B. multiplicand
C. product
D. sum

_____ **9.** All fractions must have a common _________ before one can be subtracted from the other.

A. sum
B. remainder
C. numerator
D. denominator

_____ **10.** To multiply fractions, multiply the _________ and reduce as required.

A. numerator by numerator
B. denominator by denominator
C. both A and B
D. neither A nor B

Matching — Circle

_____ **1.** Diameter

_____ **2.** Sector

_____ **3.** Arc

_____ **4.** Segment

_____ **5.** Radius

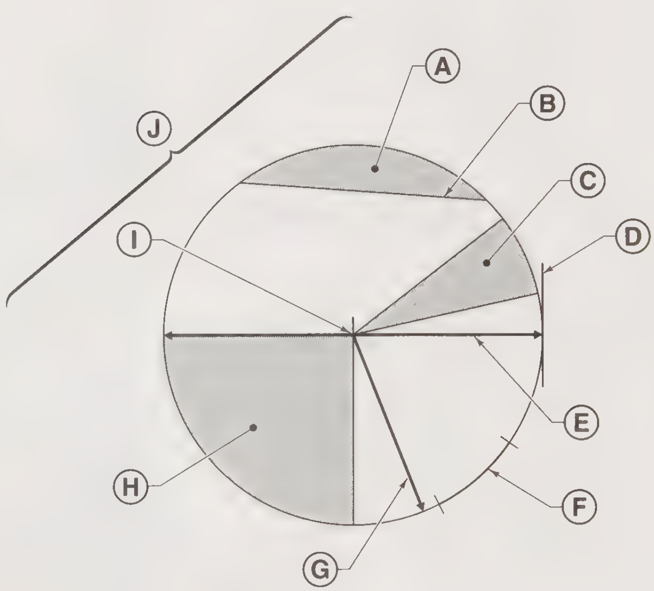
_____ **6.** Tangent

_____ **7.** Centerpoint

_____ **8.** Circle

_____ **9.** Chord

_____ **10.** Quadrant



Matching — Metrics

______	**1.** Hecto	**A.** Thousandth
______	**2.** m	**B.** Mega
______	**3.** Gram	**C.** Time symbol
______	**4.** A	**D.** Kilo
______	**5.** mm	**E.** Centi
______	**6.** M	**F.** Length symbol
______	**7.** Hundreth	**G.** Deci
______	**8.** Thousand	**H.** Ampere
______	**9.** Tenth	**I.** Hundred
______	**10.** s	**J.** Mass

Matching — Solid Figures

______ **1.** Oblique rectangular prism

______ **2.** Hexahedron

______ **3.** Torus

______ **4.** Oblique pentagonal pyramid

______ **5.** Octahedron

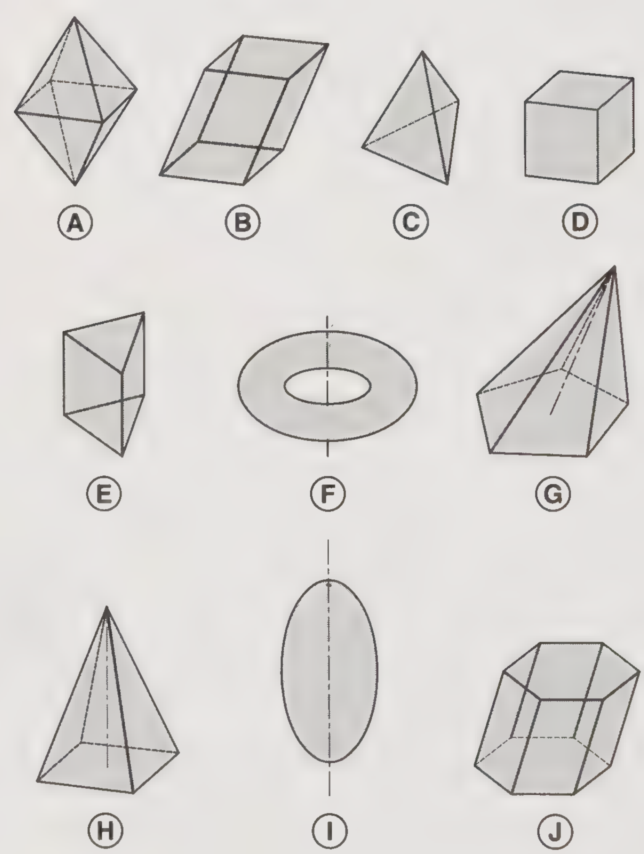
______ **6.** Right rectangular pyramid

______ **7.** Oblique hexagonal prism

______ **8.** Right triangular prism

______ **9.** Prolate ellipsoid

______ **10.** Tetrahedron

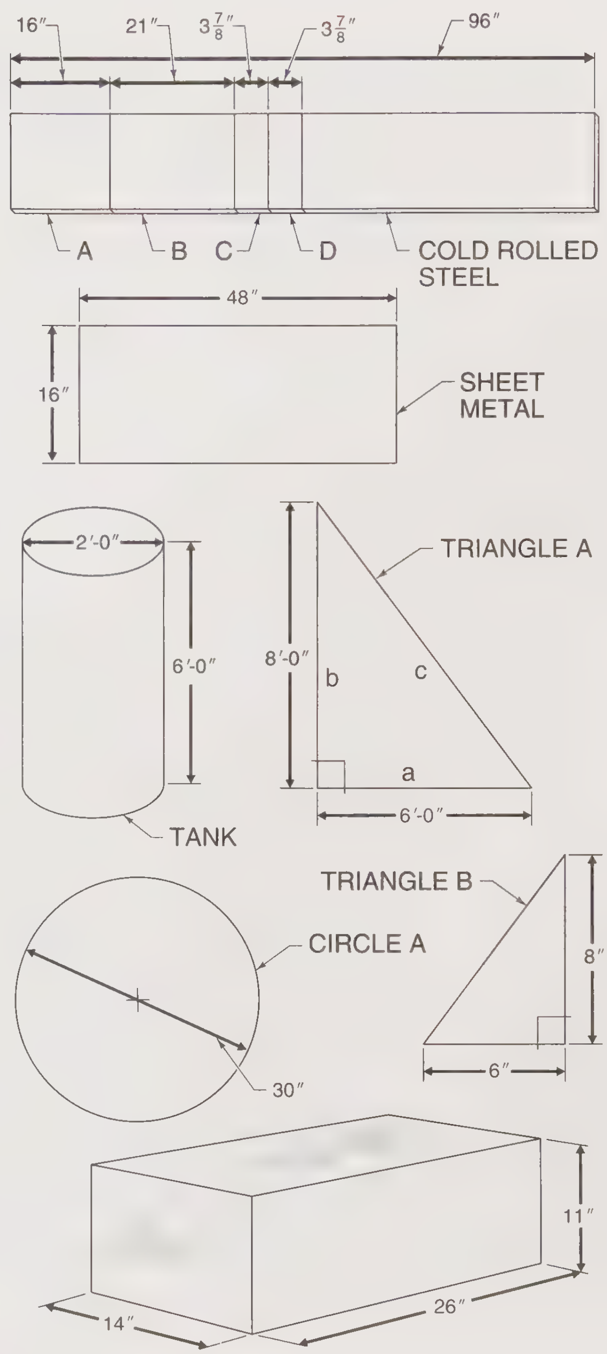


◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Word Problems



________ **1.** Four pieces (A, B, C, and D) were cut from the piece of cold rolled steel. What is the length of the remaining piece? (Disregard the cutting waste.)

________ **2.** A machinist spends $3\frac{1}{4}$ hours cutting and grinding steel to shape and $1\frac{1}{2}$ hours positioning, machining, and finishing parts to complete a job. How many hours did the job require?

________ **3.** A riveted assembly requires 32 rivets. How many rivets are required for 124 riveted assemblies?

________ **4.** How many $2\frac{1}{4}$″ × 16″ strips can be cut from the piece of sheet metal (assuming there is no cutting waste)?

________ **5.** What is the volume of the tank in cu ft?

________ **6.** What is the length of Side c of Triangle A?

________ **7.** How many VA will a 6.8 A, 120 V grinder pull under a full load?

________ **8.** What is the area of Triangle B?

________ **9.** What is the circumference of Circle A?

________ **10.** What is the volume of the rectangular solid?

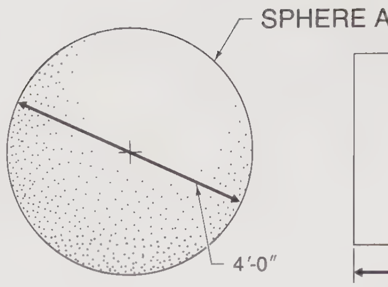
_______ **11.** What is the area of Circle A?

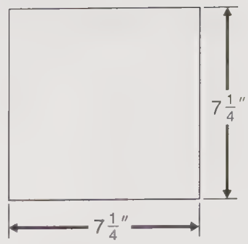
_______ **12.** What is the area of Triangle A?

_______ **13.** What is the volume of Sphere A?

_______ **14.** What is the total length of the sides of the square?

_______ **15.** What is the area of the square?





Dowel Positioner *(See page 85.)*

_______ **1.** The overall length of Part B is _______".

_______ **2.** Part _______ has rounded corners.

_______ **3.** The centers for ½" drilled holes on the left end are _______" from the right edge.

A. 5¾
B. 8
C. 8¼
D. 9¼

_______ **4.** Parts A and B are the same _______.

A. size
B. shape
C. both A and B
D. neither A nor B

T F **5.** Four ⅜" diameter holes are drilled in Part A.

_______ **6.** The horizontal center-to-center distance between the holes in Part B is _______".

_______ **7.** The Dowel Positioner was manufactured by _______.

_______ **8.** Part B has an area of _______ sq in. (disregarding the drilled holes).

_______ **9.** Part B has a volume of _______ cu in. (disregarding the drilled holes).

_______ **10.** The centerpoints of the two upper holes in Part B are _______" from the top edge of Part A.

_______ **11.** The drawing of the Dowel Positioner was completed on _______.

_______ **12.** The holes in Part A are _______" farther apart than the holes in Part B.

T F **13.** The drawing of the Dowel Positioner has been revised.

T F **14.** The overall height of the Dowel Positioner is 4¼".

T F **15.** The Dowel Positioner is made from ½" thick stock.

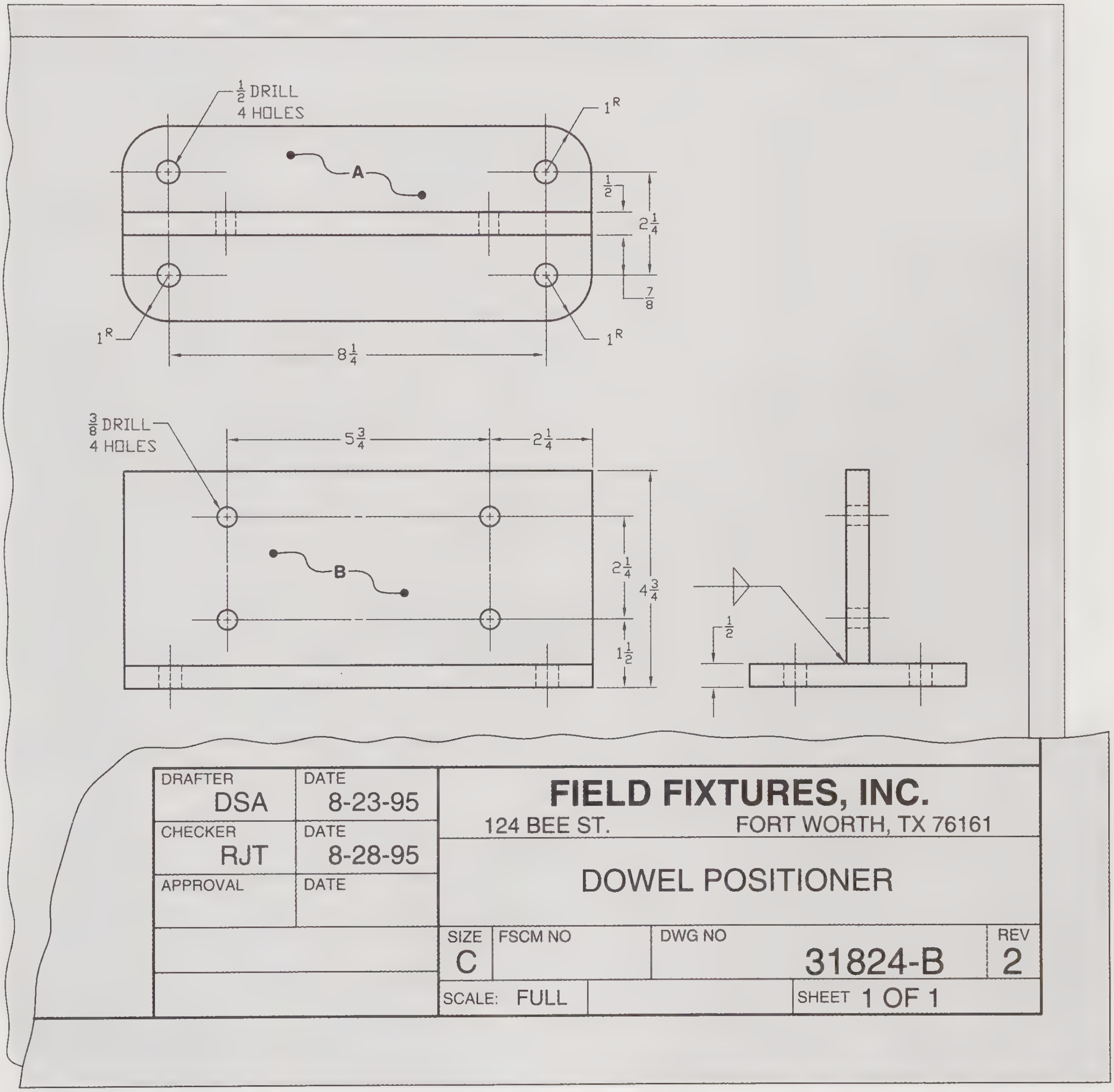
T F **16.** The holes in Part B are larger than the holes in Part A.

T F **17.** Part B is perpendicular to Part A.

__________ **18.** The radius of each rounded corner is ________″.

__________ **19.** All drilled holes are shown in the right side view with ________ lines.

__________ **20.** The overall depth of the Dowel Positioner is ________″.



DOWEL POSITIONER

End Plate

_______ **1.** The maximum distance between center lines A and B is _________″. (Decimal to 4 places)

_______ **2.** The minimum distance between center lines B and C is _________ ″. (Decimal to 3 places)

_______ **3.** The maximum distance between center lines M and L is _________″. (Decimal to 3 places)

_______ **4.** The maximum distance between center lines F and E is _________″. (Decimal to 3 places)

_______ **5.** The maximum distance between H and G is _________″. (Fraction)

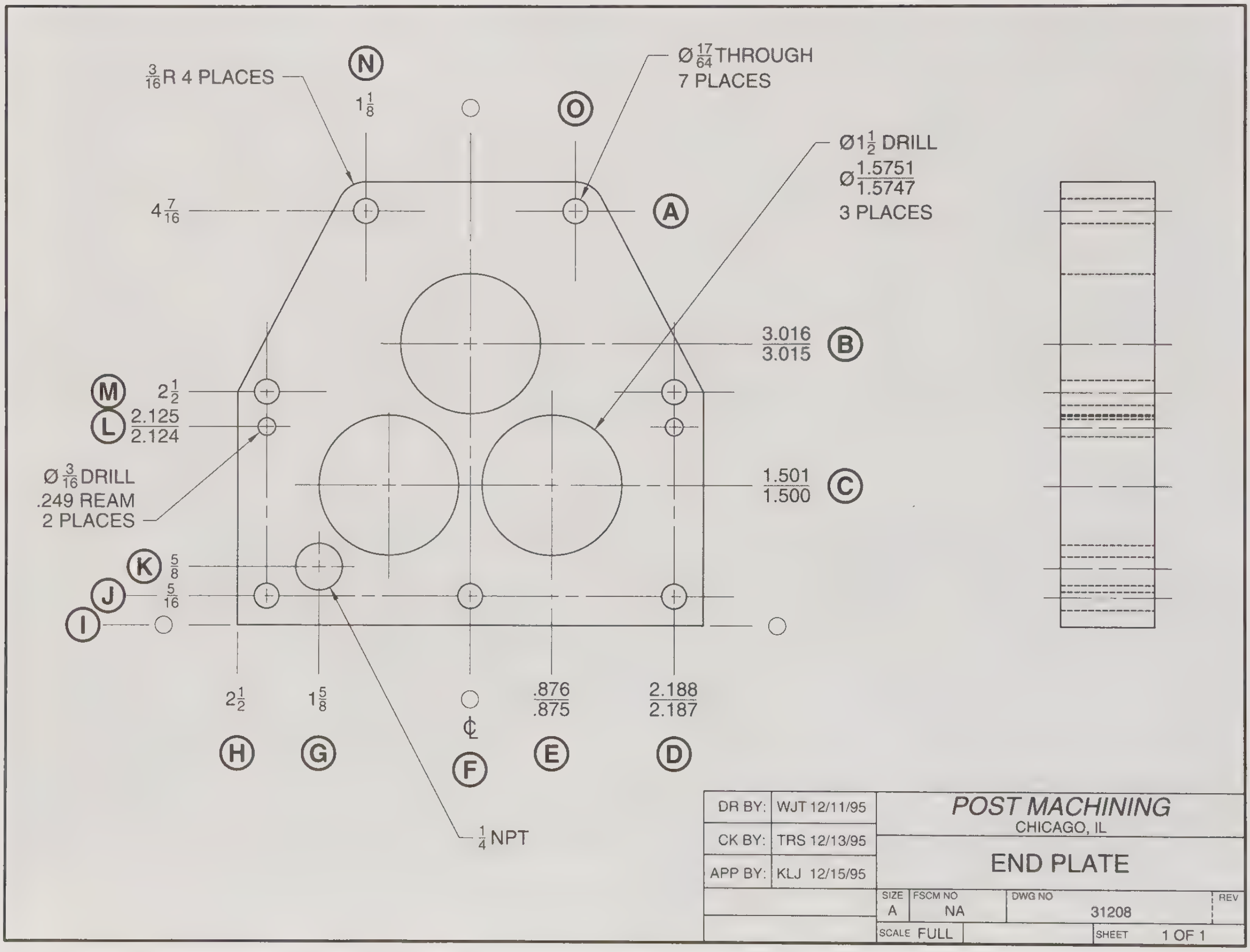
_______ **6.** The minimum distance between G and D is _________″. (Decimal to 3 places)

_______ **7.** The center-to-center distance between N and O is _________″. (Fraction)

_______ **8.** The center-to-center distance between A and K is _________″. (Fraction)

_______ **9.** The ream for the Ø3⁄16 drilled hole removes _________ ″ of material from the diameter.

_______ **10.** The decimal distance from I to the center line at J is _________″. (Decimal to 4 places)



END PLATE

chapter 4

GEOMETRIC DIMENSIONS AND TOLERANCES

Geometric dimensioning and tolerancing is a method of specifying form or location of parts in a working drawing. Advances in machining techniques have permitted greater control and accuracy in parts manufacturing. Advances in dimensioning methods were required to make certain the specifications would meet the needs of the machining techniques.

GEOMETRIC DIMENSIONING AND TOLERANCING

Geometric dimensioning and tolerancing is a method of specifying the allowable variations from an exact part. Tolerances are specified for form and location features. Current machining and measuring techniques have made it possible to maintain the very exacting tolerances required for interchangability of parts.

All parts produced vary in size and shape. Geometric dimensioning and tolerancing allows specifications to describe these variations to assure that parts work together as designed.

ANSI sets standards for the application of dimensions and tolerances on parts. These standards (ANSI Y14.5M) have been followed since their adoption in 1982. The standards apply to size, geometric form, and features that are required to completely describe any part.

TERMINOLOGY

Geometric dimensioning and tolerancing deals with five types of control features. These are form, profile, orientation, location, and runout. Tolerance of form deals with individual features. Tolerance of profile deals with either individual or related features. Tolerances of location, orientation, and runout deal with related features. The notation used on a drawing shows the type of tolerance being dimensioned, the datum(s) referenced, any modifier, and the tolerance zone. See Figure 4-1.

GEOMETRIC DIMENSIONING SYMBOLS

	TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL	ANSI
FOR INDIVIDUAL FEATURES	FORM	STRAIGHTNESS	—	6.4.1
		FLATNESS	▱	6.4.2
		CIRCULARITY (ROUNDNESS)	○	6.4.3
		CYLINDRICITY	⌭	6.4.4
FOR INDIVIDUAL OR RELATED FEATURES	PROFILE	PROFILE OF A LINE	⌒	6.5.2 (b)
		PROFILE OF A SURFACE	⌓	6.5.2 (a)
FOR RELATED FEATURES	LOCATION	POSITION	⌖	5.2
		CONCENTRICITY	◎	5.11.3
	ORIENTATION	ANGULARITY	∠	6.6.2
		PERPENDICULARITY	⊥	6.6.4
		PARALLELISM	//	6.6.3
	RUNOUT	CIRCULAR RUNOUT	↗	6.7.2.1
		TOTAL RUNOUT	⌰	6.7.2.2

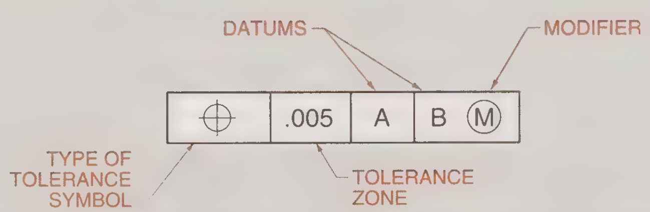


Figure 4-1. Geometric dimensioning and tolerancing deals with individual and related features.

General Terms

A *feature* is any surface, angle, hole, etc. which may be controlled on a part. Each feature of a part may be controlled in its size and shape. Features may be individual or related. *Individual features* are features applied to a specific element of a part. *Related features* are features applied to describe how one feature relates to specific datum(s).

A *datum* is a point, line, axis, or surface which serves as the origin for dimensions. Datums are used to identify related features. They are identified for each of the primary orthographic planes and any other element which is needed to establish the needed relationships. Simple parts may require only one or two datums while complex parts may require many.

Datums are identified using uppercase letters enclosed in a frame. Datum targets are used to establish the relationship between specific points on uneven surfaces such as castings, forgings, or weldments. Targets are located with a datum target symbol. A datum target symbol uses a circular frame, a letter, and a number to specify the reference. See Figure 4-2. Each letter of the alphabet may be used except I, O, and Q. If more than 23 datums are required, AA through AZ may be used.

Datums are identified in the notations in their order of importance for the feature. There may be primary, secondary, and tertiary datums identified. In addition, multiple datums may be identified as primary. See Figure 4-3.

A *basic dimension* is a numeric value used to describe a theoretical exact size, shape, or location of a feature. It serves as the basis for establishing permissible tolerances. A basic dimension is identified by enclosing it in a separate frame. See Figure 4-4.

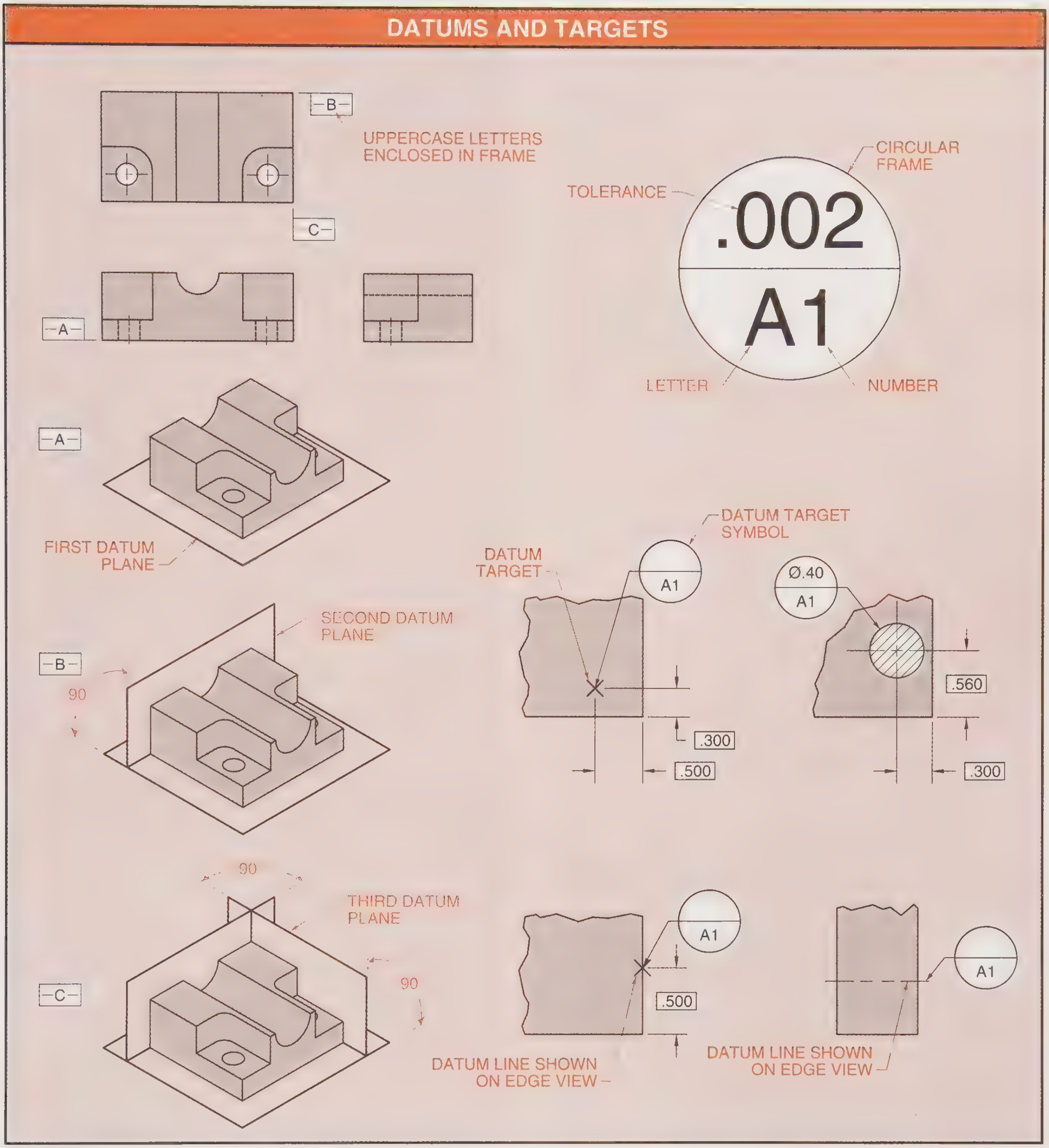


Figure 4-2. Datums and targets are used to specify origins for dimensions.

Individual Features. Tolerances of form relate to individual features. These tolerances specify the maximum permissible variation of desired surface conditions for straightness, flatness, roundness, or cylindricity. See Figure 4-5. Form tolerances stipulate how far the part can vary from the theoretical geometric figure. For example, a piece of square bar stock may have a straightness tolerance of .002″.

Individual and Related Features. Profile tolerances may be applied to either individual features or related features. They are used to describe the variation permissible from a specified theoretical profile. See Figure 4-6.

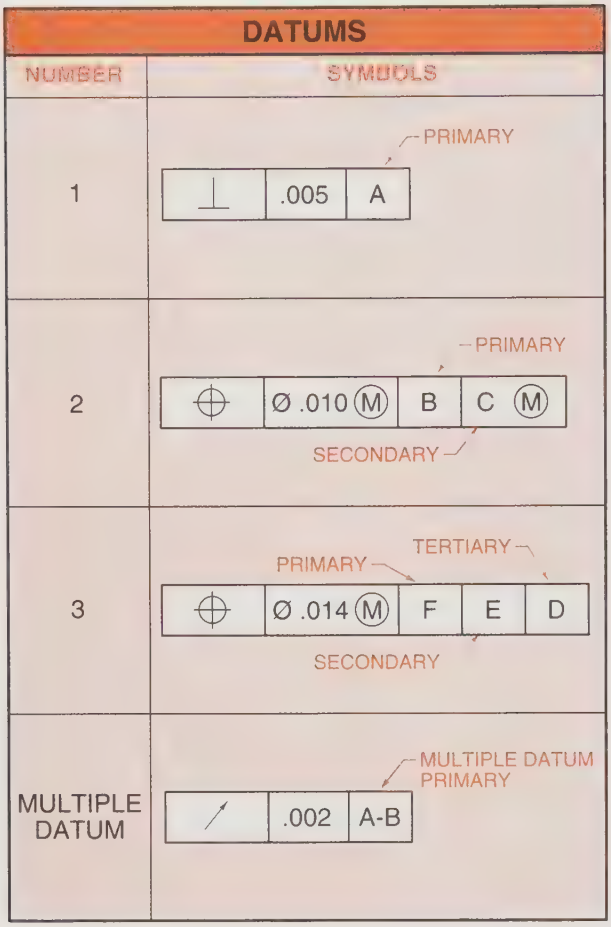


Figure 4-3. Datums are specified in order of importance to the specified feature.

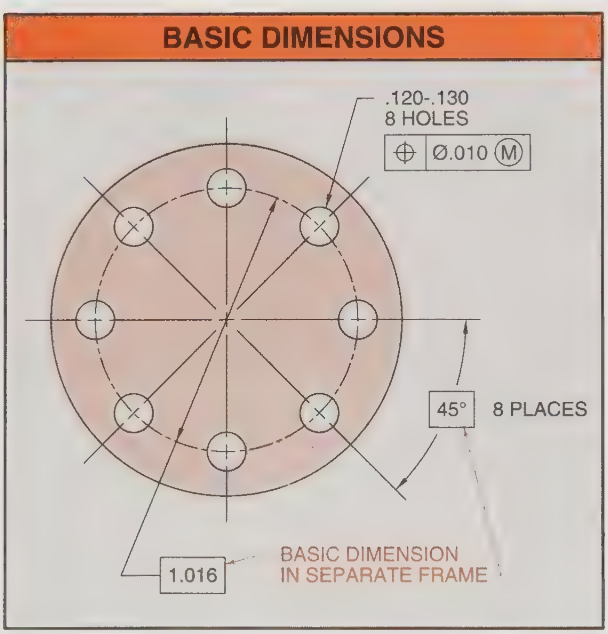


Figure 4-4. Basic dimensions are specified in frames.

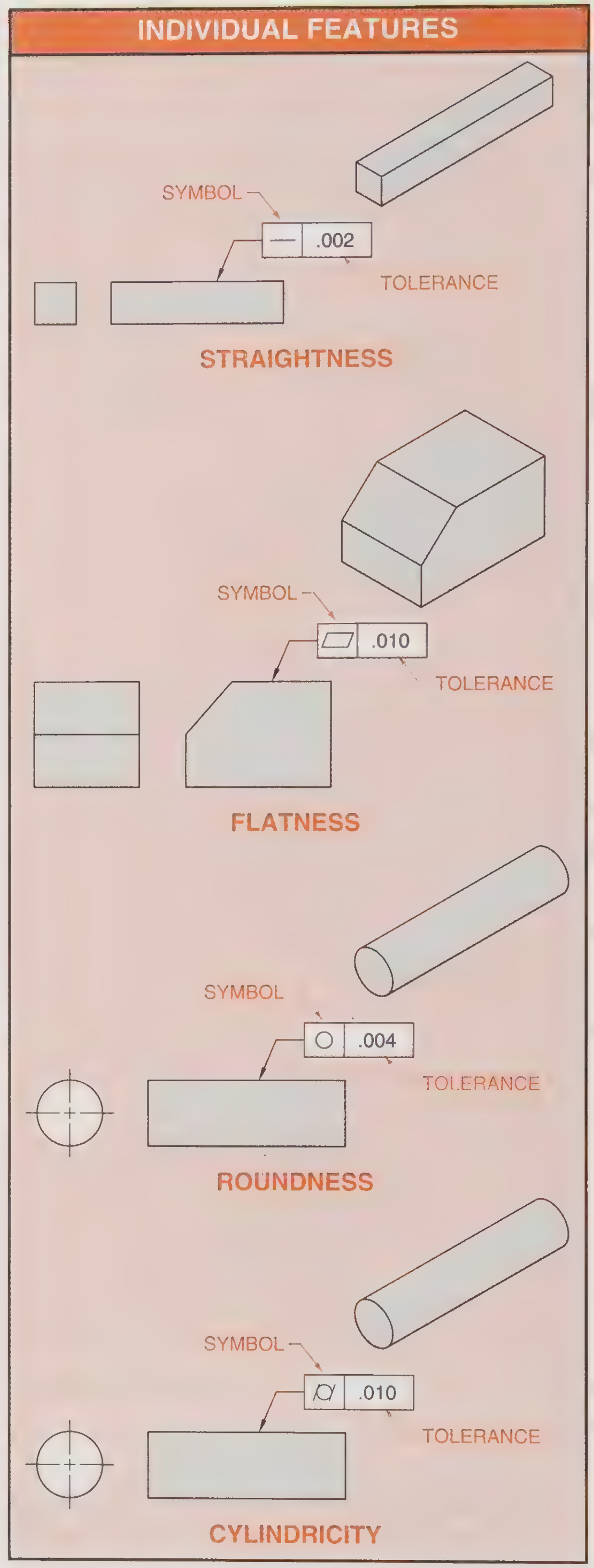


Figure 4-5. Individual features refer to the straightness, flatness, roundness, or cylindricity of a part.

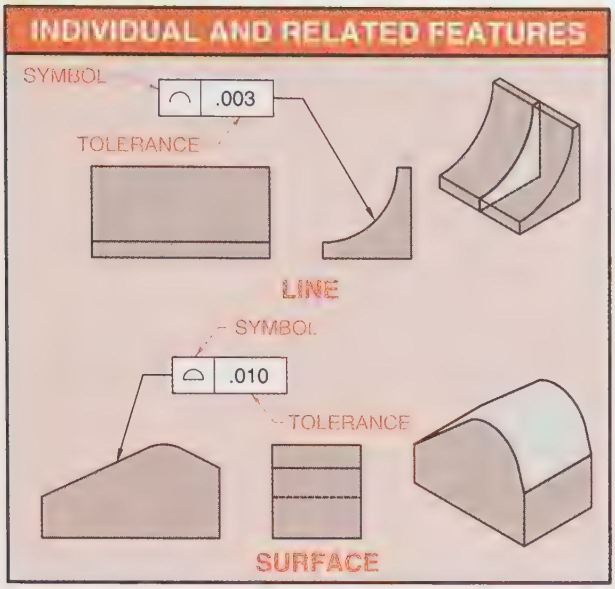


Figure 4-6. Individual and related features refer to profile tolerances.

Related Features. Tolerances of location, orientation, and runout may be specified for related features. Each of these specifies the permissible variation from a relationship.

Location is a tolerance that refers to the position of one feature in relation to one or more datum features. These may be either position or concentricity tolerances. See Figure 4-7.

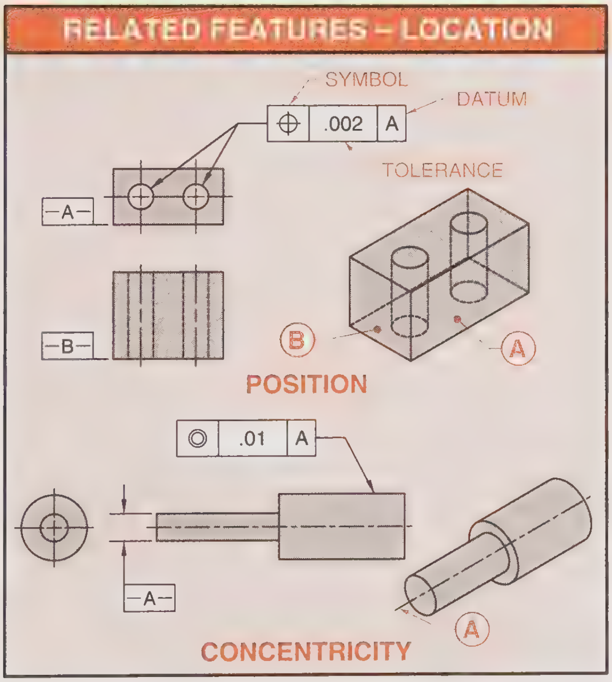


Figure 4-7. Location refers to the position of one feature in relation to one or more datum features.

Orientation is a tolerance that refers to the relationship between lines and surfaces. Orientation tolerances may refer to parallelism, perpendicularity, or angularity. See Figure 4-8.

Runout is a composite tolerance that controls the relationship of one or more features to a datum axis. These may be surfaces constructed around an axis or perpendicular to an axis. Runout is circular or total. See Figure 4-9.

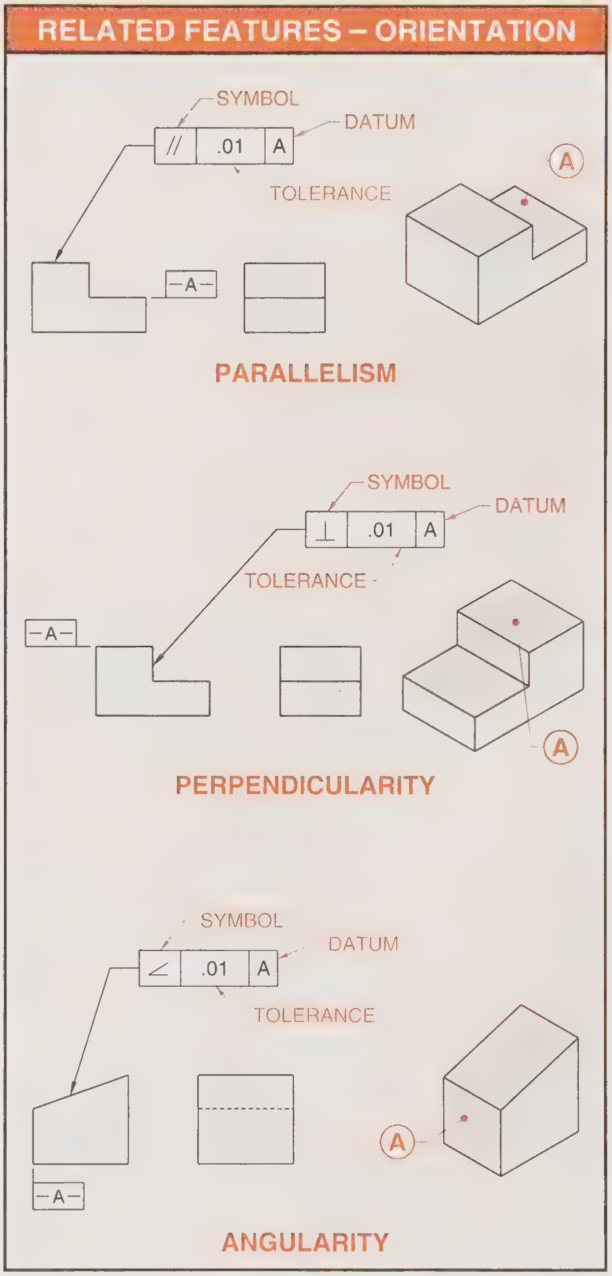


Figure 4-8. Orientation refers to the relationship between lines and surfaces.

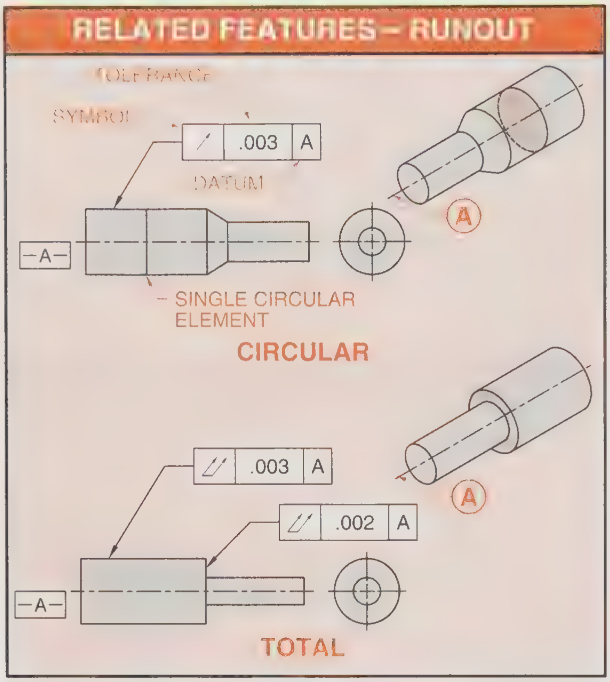


Figure 4-9. Runout is a composite tolerance that controls the relationship of one or more features to a datum axis.

Modifiers

Modifiers are symbols that convey specific information needed to clarify some aspect of a feature. These generally relate to size or material condition. Modifiers are designated on drawings with the encircled letters M (Maximum Material Condition), L (Least Material Condition), S (Regardless of Feature Size), or P (Projected Tolerance Zone).

Maximum Material Condition (MMC). This condition is represented by an encircled M. *MMC* refers to the maximum amount of material permitted by the tolerance zone. For holes, slots, and other internal features this is the minimum allowable size. For all external features, this is the maximum allowable size. See Figure 4-10.

Least Material Condition (LMC). This is the opposite of MMC and represented by an encircled L. *LMC* refers to the minimum amount of material permitted by the tolerance zone. For all internal features this is the maximum allowable size for the feature. For all external features, this is the minimum permissible size. See Figure 4-11.

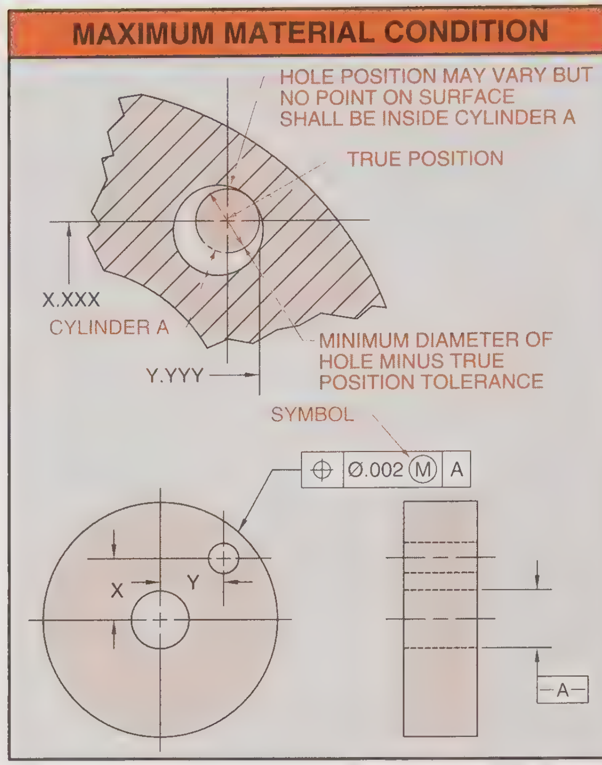


Figure 4-10. Maximum material condition exists when a hole is at its smallest permissible size.

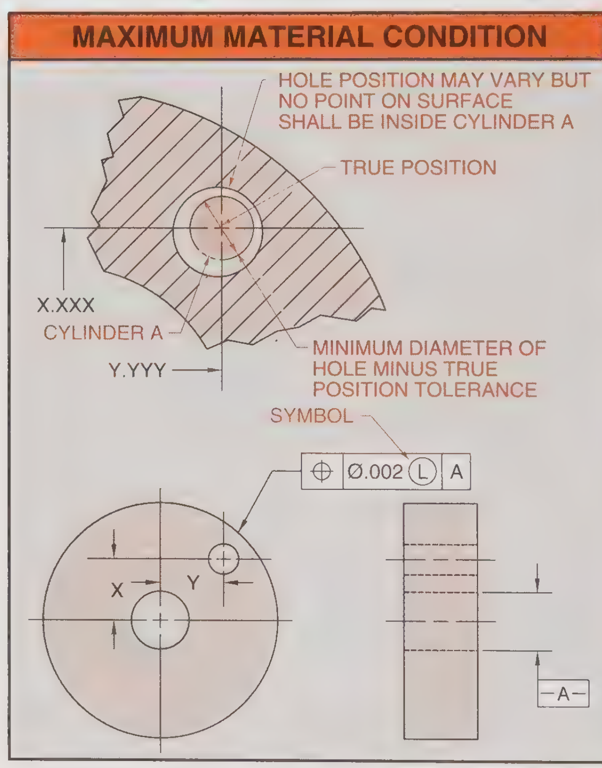


Figure 4-11. Least material condition exists when a hole is at its largest permissible size.

Regardless of Feature Size (RFS). The designation RFS is represented using an encircled S. *RFS* indicates that all positional tolerances must be met regardless of where the feature lies within the tolerance zone. RFS is assumed if no modifier is used in the notation. For circular features, the axis of each feature must be located rather than the surfaces. See Figure 4-12.

REGARDLESS OF FEATURE SIZE

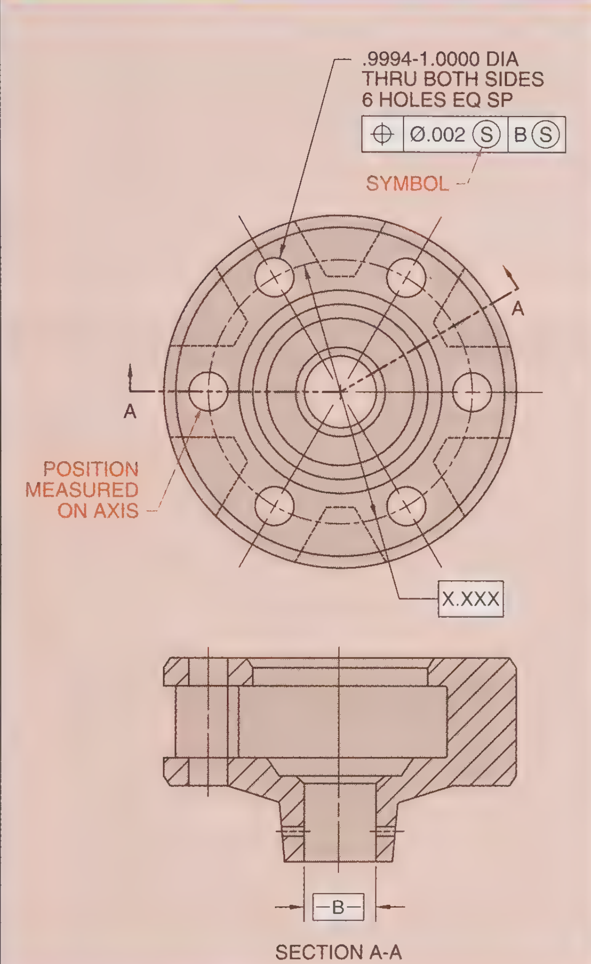


Figure 4-12. Regardless of feature size is applied for positional tolerances.

Projected Tolerance Zone. An encircled P is used to specify the projected tolerance zone. It is used where variations in perpendicularity of threaded holes or press fit holes may cause interference between mating parts. See Figure 4-13.

PROJECTED TOLERANCE ZONE

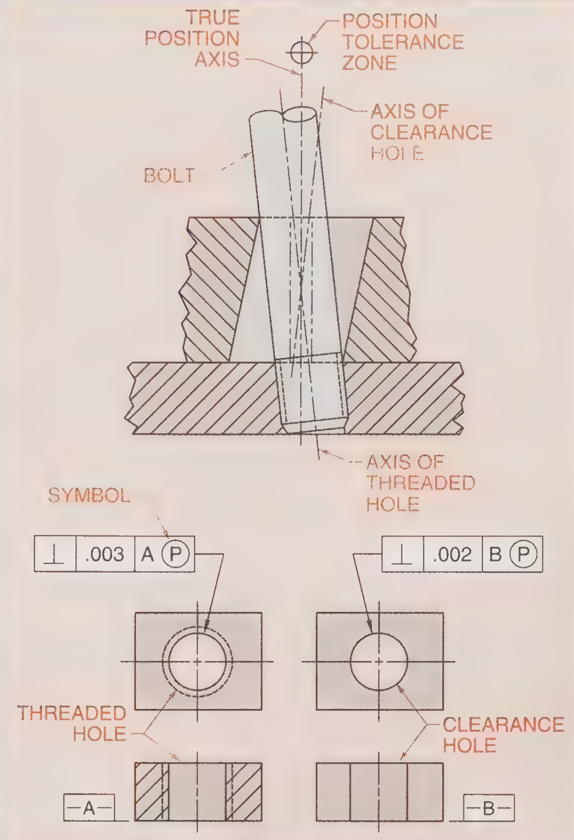


Figure 4-13. Projected tolerance zone is applied to mating parts to determine fit.

SYMBOLS

Symbols are used to specify the type of tolerance being applied to a feature. Each of these tolerances refer to a characteristic of the part being dimensioned. Symbols used include form, profile, orientation, location, and runout.

Form

Tolerances of form refer to how well a feature meets a theoretical feature. They are not related to any datum. Tolerances of form include straighness, flatness, roundness, and cylindricity.

Straightness. The theoretical straight object is one that has an axis on its surface and an axis through it in a common plane. It neither bends nor is concave or convex. See Figure 4-14.

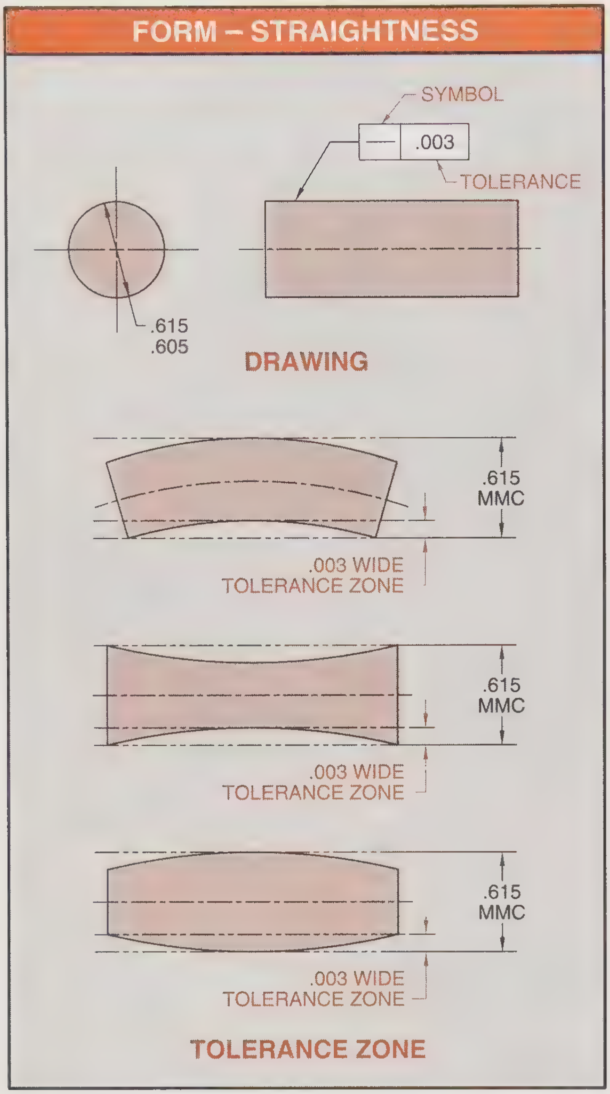


Figure 4-14. Straightness of a part indicates it is in a single plane.

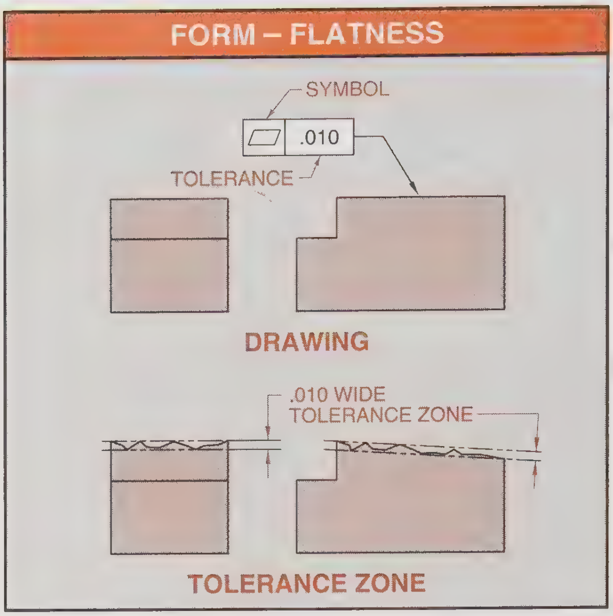


Figure 4-15. Flatness provides a tolerance zone where all points on a surface must lie.

Flatness. The theoretical flat plane does not have any surface variation. The specified tolerance provides a range between two parallel planes where all points on the surface shall lie. See Figure 4-15.

Roundness. The cross section of an object shall be in a tolerance zone that is circular. There is no consideration given to the surface of the object except where the section is taken. See Figure 4-16.

Cylindricity. The tolerance zone specifies where the surface of the cylinder will fall. The zone is established by two concentric cylinders. See Figure 4-17.

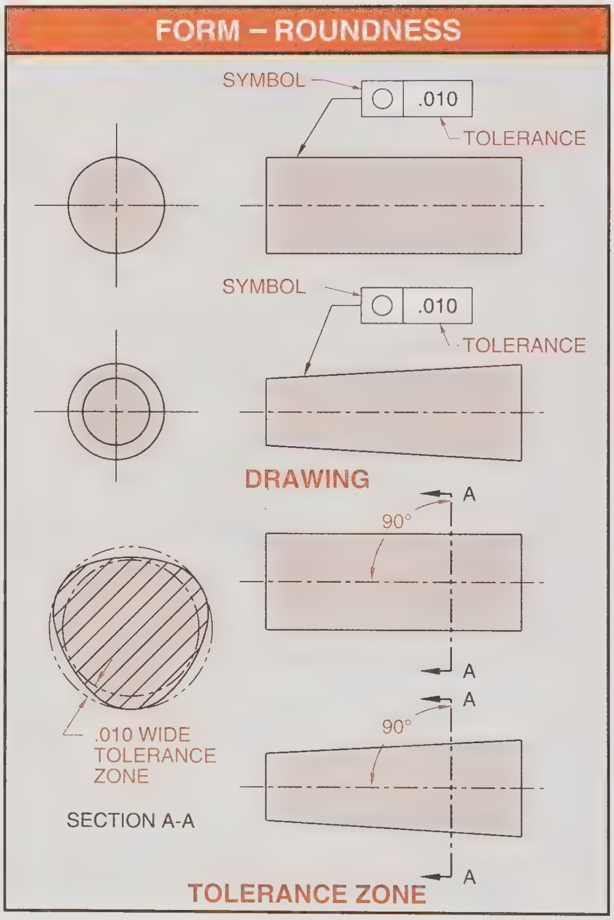


Figure 4-16. Roundness refers to the cross section of an object.

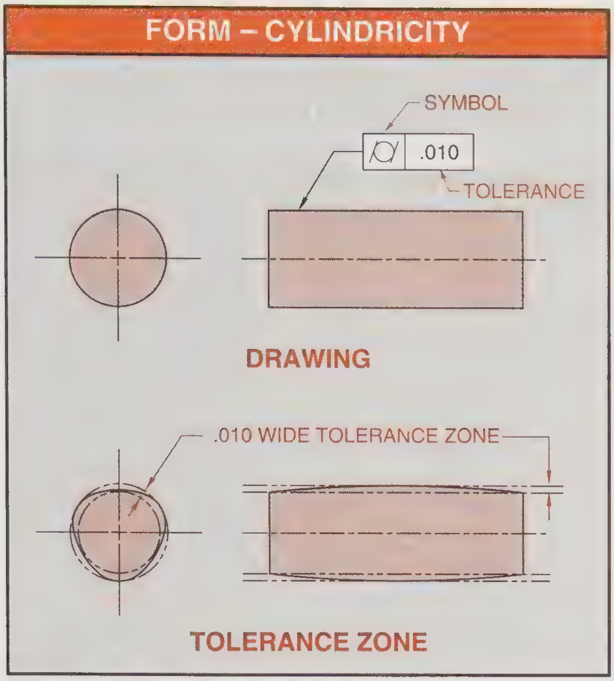


Figure 4-17. Cylindricity refers to a tolerance zone of two concentric cylinders.

Profile

A profile tolerance is the outline of any object as shown on a given plane and represents a surface or a line. Tolerances of profile include line and surface.

Line. The tolerance zone is given around a line in a cross section of a surface. This tolerance may be referenced to a datum. It is usually specified between two points. See Figure 4-18.

Surface. The tolerance zone is given around the entire surface. It may be specified with reference to a datum. See Figure 4-19.

Orientation

Orientation tolerancing for related features involves the control of the relationship between two or more lines or surfaces. Tolerances of orientation include angularity, perpendicularity, and parallelism.

Angularity. Tolerancing angularity relates a surface or axis to a datum surface or axis. See Figure 4-20.

Perpendicularity. Tolerancing perpendicularity relates a surface or axis at right angles to a datum surface or axis. See Figure 4-21.

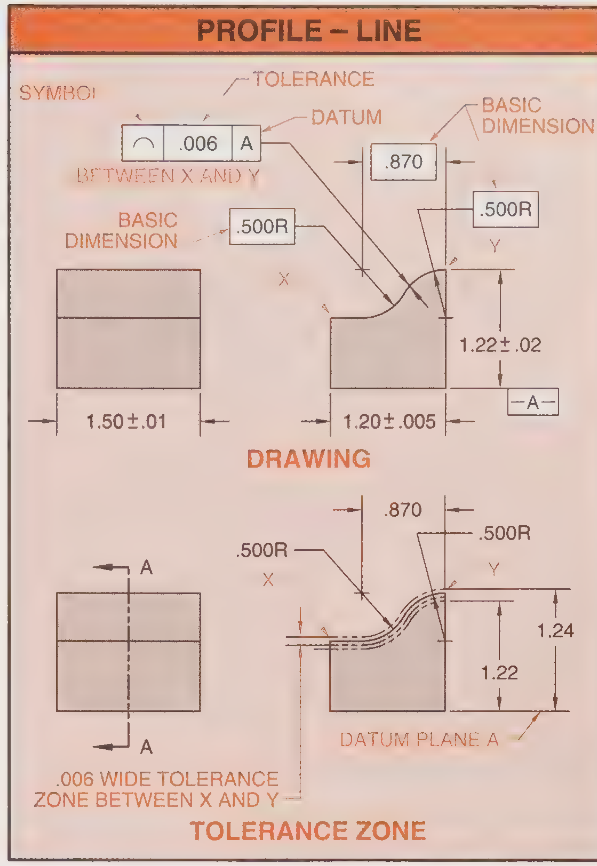


Figure 4-18. Profile of a line is given around a cross section.

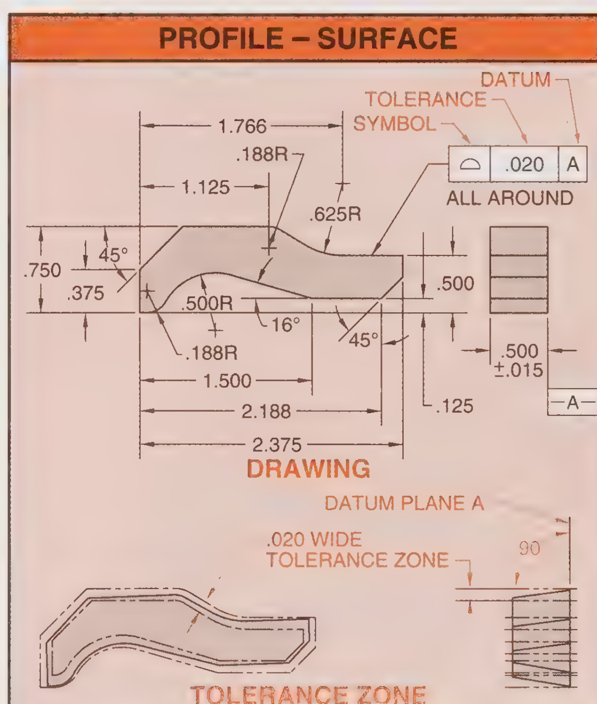


Figure 4-19. Profile of a surface is around the entire area.

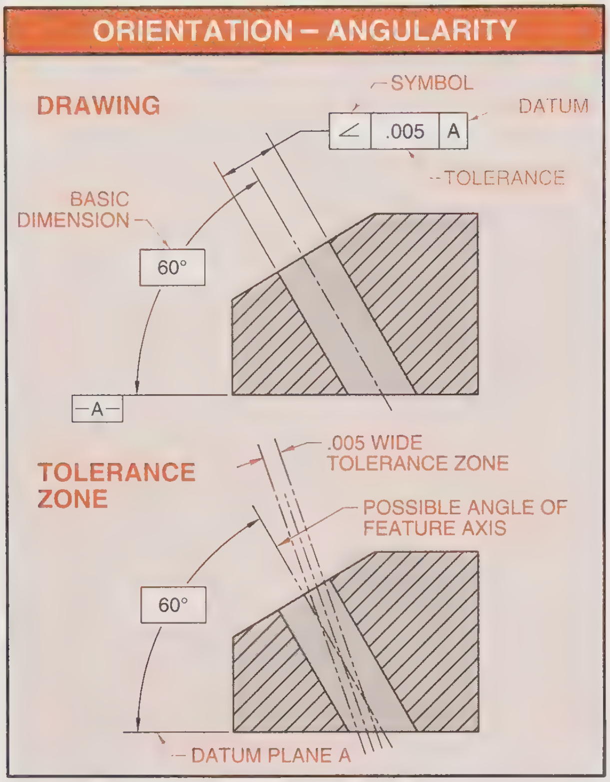


Figure 4-20. Angularity relates a feature at a specified angle to a datum.

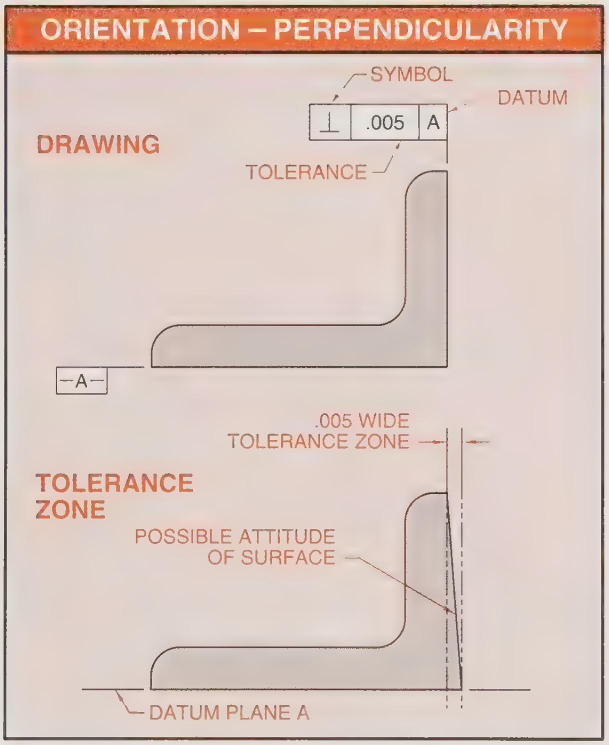


Figure 4-21. Perpendicularity relates a feature at a right angle to a datum.

Parallelism. Tolerancing parallelism relates a surface or axis that is equidistant from all points on a datum surface or axis. See Figure 4-22.

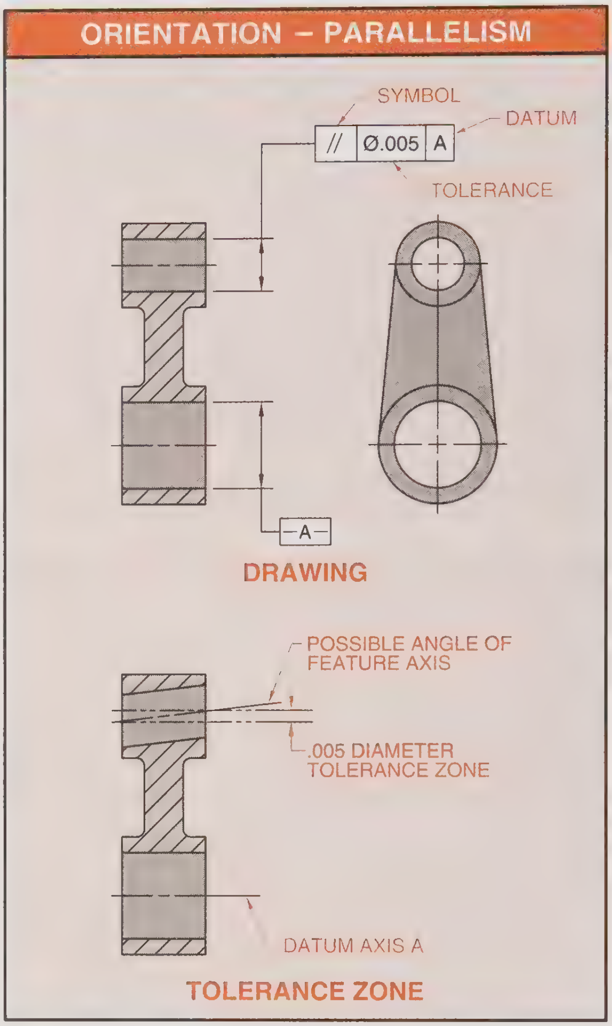


Figure 4-22. Parallelism relates a feature equidistant from a datum.

Location

Tolerance of location controls the relationship of holes, slots, bosses, tabs and the like to each other and to datums. Tolerances of location include position and concentricity.

Position. A positional tolerance defines the zone which will contain the center plane of a feature. Basic dimensions are used to establish the true position. The tolerance is given in the geometric tolerance symbol. See Figure 4-23.

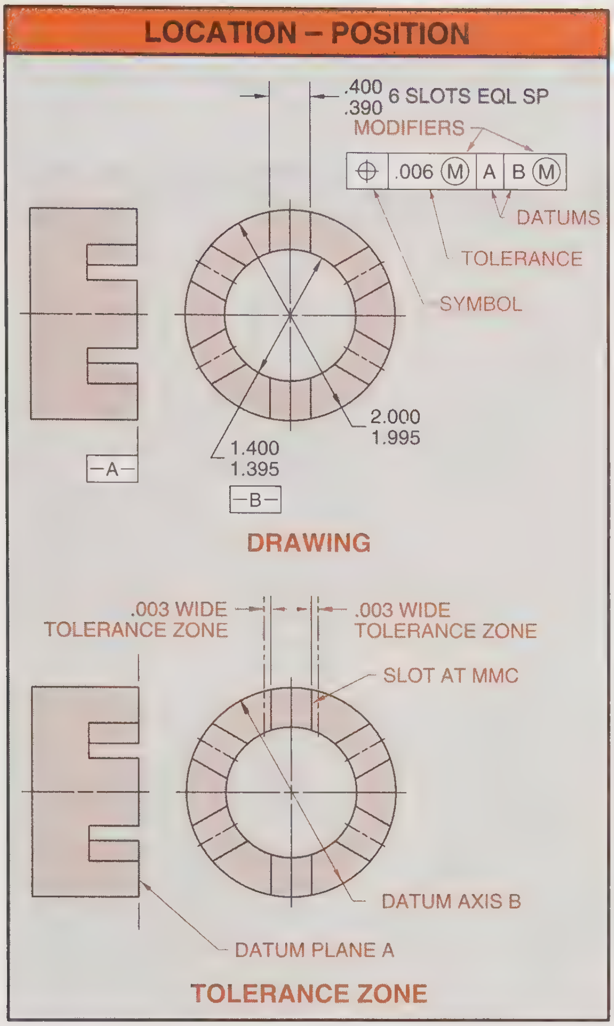


Figure 4-23. Positional tolerances provide clear descriptions of the location of features.

Concentricity. The concentricity tolerance deals with permissible variations when the surfaces involved are cylinders, spheres, cones, and the like. Tolerances are given as they relate to a datum axis. See Figure 4-24.

Runout

Runout tolerances control the relationship of one or more features to a datum axis. Tolerances of runout include circular and total.

Circular. A circular runout provides control of a circular element of a surface. The specified tolerance relates a cross section to a datum axis. See Figure 4-25.

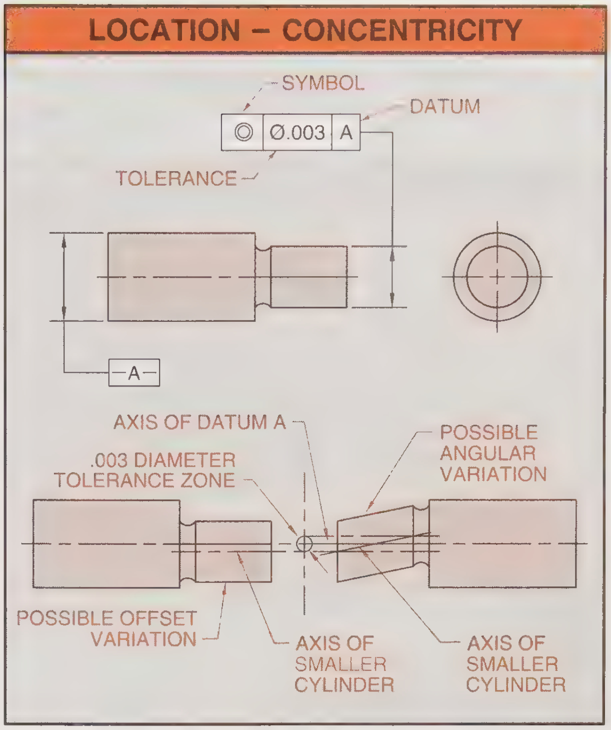


Figure 4-24. Concentricity specifies the relationship between a datum axis and circular features.

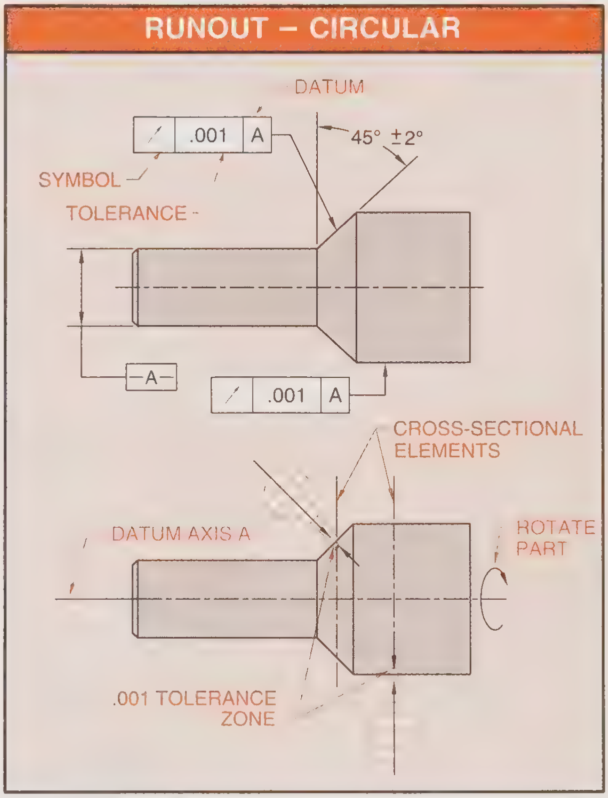


Figure 4-25. Circular runout refers to specific measuring positions.

Total. A total runout relates the entire surface area to a datum axis. Runout is measured by rotating the part around the datum axis and measuring variations with a dial indicator. The total indicator reading (TIR) must fall within the tolerance zone for the part to be acceptable. *TIR* is the maximum variation from smallest to largest indicator reading. See Figure 4-26.

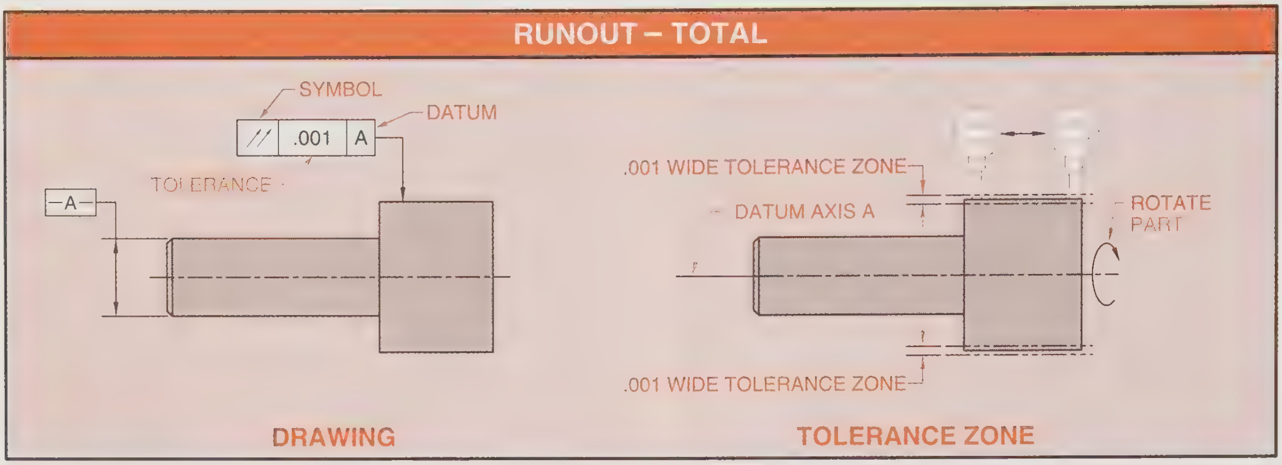
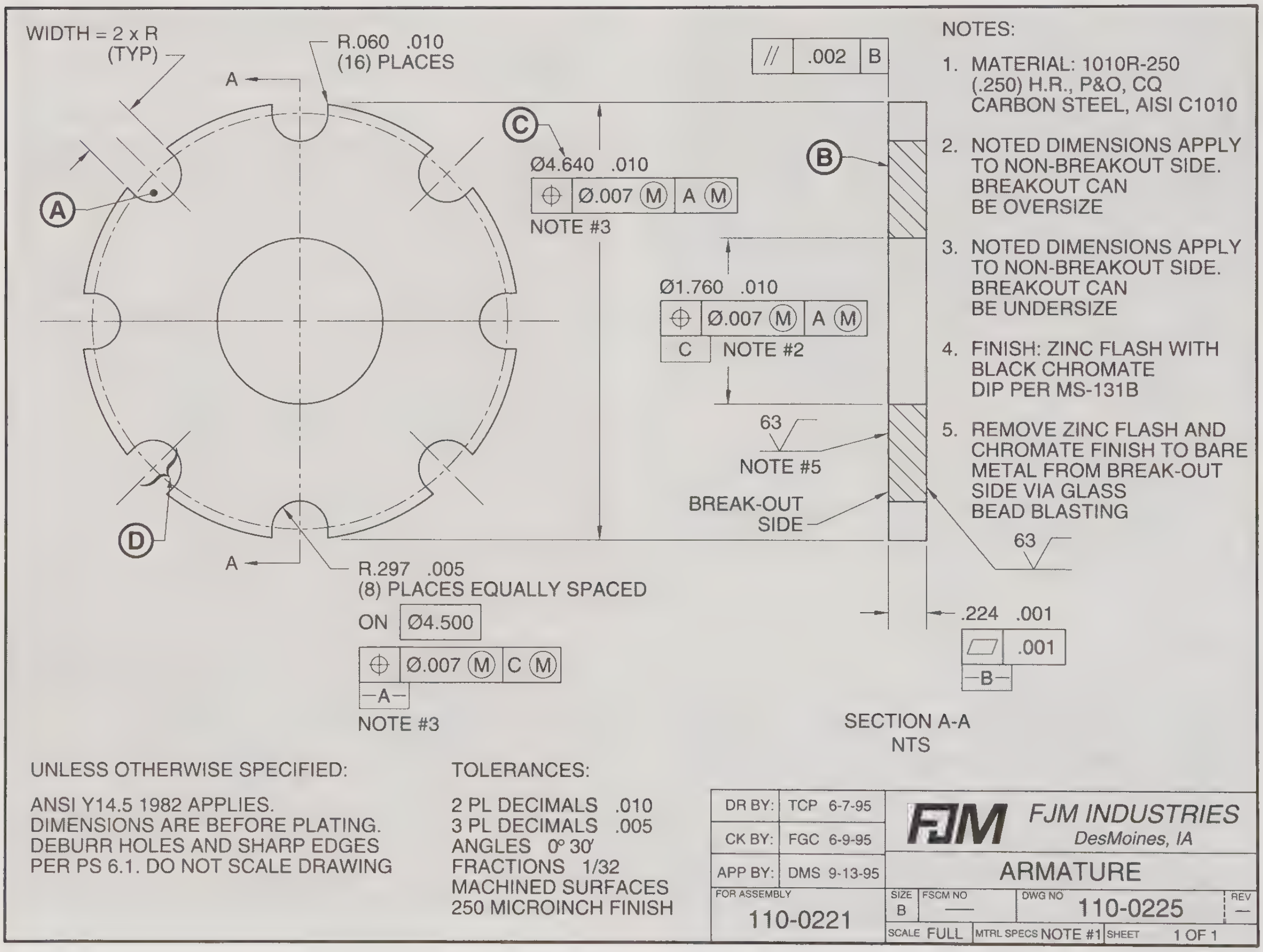


Figure 4-26. Total runout applies the tolerance to an entire surface area.



ARMATURE

Review Questions

Name ______________________________ Date ______________

True-False

T F 1. Tolerances may be specified for form and size.

T F 2. A feature is any surface, angle, or hole in an object.

T F 3. Simple parts may require only one datum to tolerance features.

T F 4. Basic dimensions show theoretical exact sizes.

T F 5. Tolerances of form describe related features.

T F 6. Tolerances of location refer to parallelism, angularity, and perpendicularity.

T F 7. A flat plane has no surface variations.

T F 8. Runout may be either circular or rectangular.

T F 9. Profile tolerances deal with related or individual features.

T F 10. A hole at MMC is as large as possible with a given tolerance.

Completion

__________ 1. Perpendicularity relates lines or surfaces at _________ angles to each other.

__________ 2. Basic dimensions are used to establish a(n) _________ position.

__________ 3. All parts vary in size and _________.

__________ 4. _________ refers to the minimum material allowed by the tolerance zone.

__________ 5. Form tolerances specify how well an actual feature meets a(n) _________ feature.

__________ 6. Datums are specified using uppercase letters enclosed in a(n) _________.

__________ 7. If the feature size does not affect the tolerance zone, a(n) _________ modifier is specified.

__________ 8. An outline of a surface as it appears on a given plane is called a(n) _________.

__________ 9. Symbols that convey information to clarify some aspect of a feature are called _________.

__________ 10. Runout tolerances are specified with reference to a datum _________.

__________ 11. Where mating parts are toleranced, a(n) _________ tolerance zone may be identified.

________ 12. A(n) ________ tolerance may refer to individual or related features.

________ 13. ________ may be used to locate datums on uneven surfaces.

________ 14. Any feature that applies to a specific element of a part is a(n) ________ feature.

________ 15. Related features must always be related to one or more ________.

Matching — Feature Controls

________ 1. Angularity

________ 2. Parallelism

________ 3. Flatness

________ 4. Concentricity

________ 5. Straightness

________ 6. Perpendicularity

________ 7. Circularity

________ 8. Profile of a surface

________ 9. Circular runout

________ 10. True position

________ 11. Profile of a line

________ 12. Cylindricity

Matching — Modifiers

________ 1. Diameter

________ 2. Basic dimension

________ 3. Least material condition

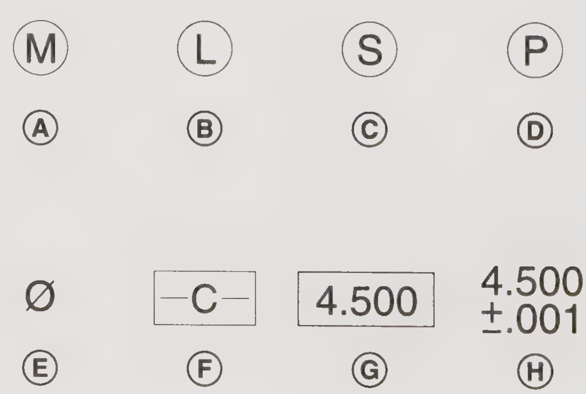
________ 4. Datum

________ 5. Maximum material condition

________ 6. Regardless of feature size

________ 7. Projected tolerance zone

________ 8. Toleranced dimension



◎ .0005 TIR A

Trade Competency Test

Name ______________________ Date ______________

Armature *(See page 98.)*

______ **1.** All dimensions specified with three decimal places have a tolerance of ±________″.

______ **2.** The Armature is made of ________ steel.

T F **3.** Datum B is the breakout side of the stamped part.

______ **4.** The minimum width of slot A is ________″.

______ **5.** When specified, all material conditions for each tolerance is at ________.

______ **6.** The Armature has a maximum thickness of ________″.

______ **7.** Datum A is positioned with reference to datum ________.

______ **8.** Datum B is ________ within a .001 tolerance zone.

______ **9.** The center hole may be ________ on the breakout side.

______ **10.** There are ________ slots around the circumference of the Armature.

T F **11.** The breakout side of the part may be larger than the ∅4.650 dimension.

______ **12.** All position tolerance zones are given as a ∅________″.

______ **13.** Surface B is ________ to datum B.

______ **14.** The size of datum C at MMC is ________″.

______ **15.** This drawing is made in compliance with ANSI ________.

T F **16.** The breakout side of the part is cleaned using glass bead blasting.

______ **17.** The corners of the slots are rounded to a(n) ________″ radius.

______ **18.** The drawing was made on a size ________ sheet.

______ **19.** The slots are located around a circle with a(n) ________ dimension of ∅4.500.

T F **20.** Two place decimals are toleranced to a .020″ zone.

______ **21.** Material specifications are found in ________.

T F **22.** A black chromate dip is used to zinc flash the Armature.

______ **23.** The true position of C is toleranced to datum ________.

_______ 24. The slots are separated by an angle of _______°.

_______ 25. The minimum distance for depth D is _______″.

_______ 26. Finishing requirements are specified in _______.

A. Note 3
B. Note 4
C. Note 5
D. Notes 4 and 5

_______ 27. Angles are accurate to a tolerance of _______.

A. ±¼°
B. ±0°30′
C. ±1°
D. ±2°

_______ 28. Machined surfaces are finished to a _______ finish.

A. 63 microinch
B. 100 microinch
C. 125 microinch
D. 250 microinch

_______ 29. The Armature is used in assembly _______.

_______ 30. The final drawing was approved by _______.

A. TCP
B. FGC
C. CTH
D. DMS

_______ 31. The drawing is made to _______ scale.

T F 32. The drawing may be scaled to obtain measurements.

T F 33. The Armature is drawing number 110-0221.

_______ 34. The drawing was completed on _______.

A. 6-7-95
B. 6-9-95
C. 6-13-95
D. 6-15-95

_______ 35. The drawing was checked by _______.

A. DMS
B. FGS
C. TCP
D. WJD

chapter 5

THREADS AND FASTENERS

Threads are used for fastening, adjusting, and transmitting power. Fasteners are devices that join or fasten parts together. They may be threaded or non-threaded. Threaded fasteners are easily installed or removed. Non-threaded fasteners are more permanent. Threaded and non-threaded fasteners must meet ANSI standards.

THREADED FASTENERS

Threaded fasteners are devices such as nuts and bolts that join or fasten parts together with threads. Threaded fasteners have several advantages for joining parts. For example, threaded fasteners are commercially available in a variety of sizes, styles, strengths, and materials and are capable of joining similar or dissimilar materials. They are easily installed in the shop or the field with hand or power tools and are easily removed and replaced.

Threaded fasteners are based upon the principle of an inclined plane wrapped around a cylinder. A *screw thread* is a ridge of uniform section in the form of a helix on the internal or external surface of a cylinder, or in the form of a conical spiral on the internal or external surface of a cone or frustum of a cone. A *helix* is the curve traced on a cylinder or cone by a point rotating at a right angle to the axis. A thread formed on a cylinder is a straight or parallel thread. A *taper thread* is the thread formed on a cone or frustum of a cone. See Figure 5-1.

Terms For Types of Screw Threads

Threads are external or internal and right- or left-handed. They are either single or multiple. See Figure 5-2. See ANSI Y14.6.

External thread. A thread on the external surface of a cylinder or cone. Threads on bolts are external.

Internal thread. A thread on the internal surface of a hollow cylinder or cone. Threads on nuts are internal.

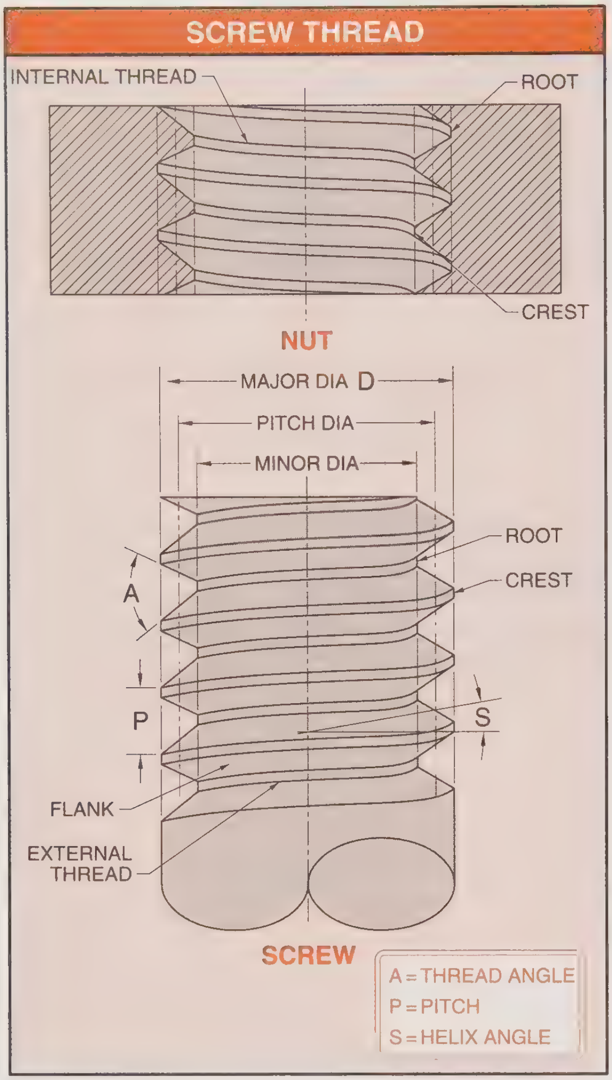


Figure 5-1. A screw thread is a ridge of uniform section in the form of a helix on the internal or external surface of a cylinder.

Right-hand thread. A thread is a right-hand thread if, when viewed axially, it winds in a clockwise and receding direction. A right-hand thread always slopes up to the right regardless of the position it occupies. Right-hand threads are the most common. Threads are assumed to be right-handed, unless otherwise specified.

Left-hand thread. A thread is a left-hand thread if, when viewed axially, it winds in a counterclockwise and receding direction. A left-hand thread always slopes up to the left regardless of the position it occupies. Left-hand threads are generally only used in applications where a right-hand thread would be subject to spin off and become disengaged. All left-hand threads are designated LH.

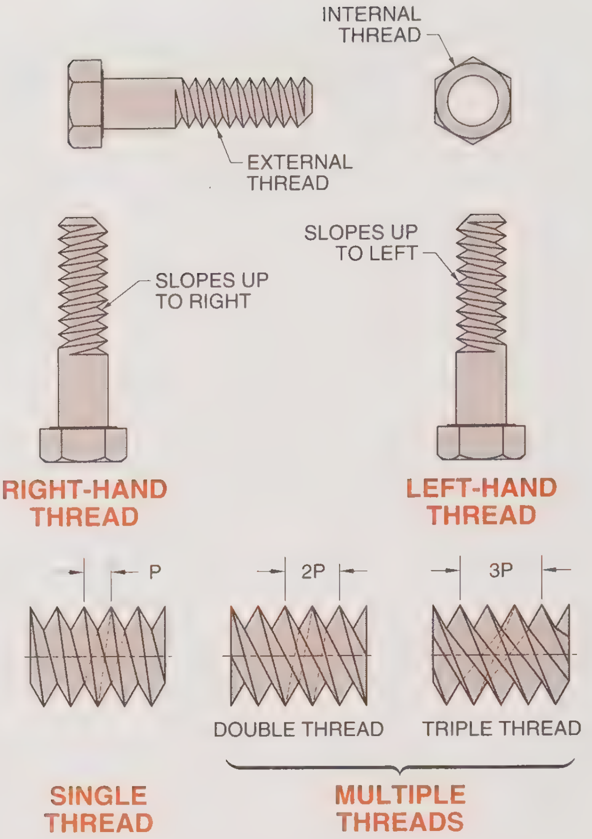


Figure 5-2. Threads are external or internal and right- or left-handed. They are either single or multiple.

Single thread. A thread with the lead equal to the pitch.

Multiple thread. A thread in which the lead is an integral multiple of the pitch.

Terms For Geometrical Elements of Screw Threads

The geometrical elements of screw threads are the cross-sectional shapes of the thread form. Thread forms (profiles) may be unified (V), knuckle, square, acme, or buttress. See Figure 5-3.

Form. The thread's profile in an axial plane for a length of one pitch.

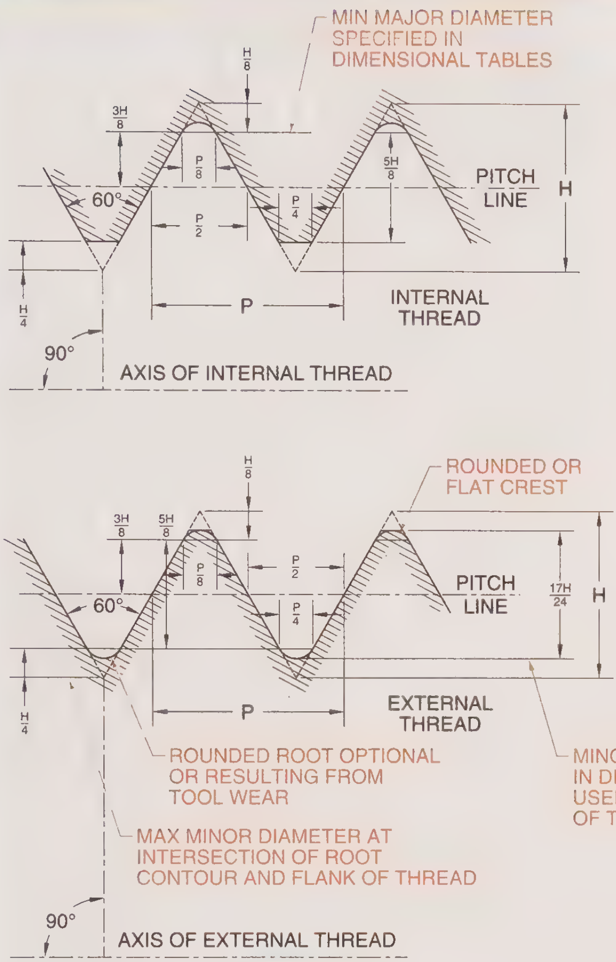
Flank (side). Either surface connecting the crest with the root, the intersection of which with an axial plane, is a straight line.

Crest. The surface that joins the flanks of the thread and is farthest from the cylinder or cone from which the thread projects.

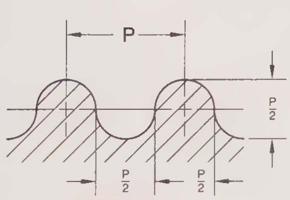
Root. The surface that joins the flanks of adjacent thread forms and is identical in position with, or immediately adjacent to, the cylinder or cone from which the thread projects.

THREAD FORMS

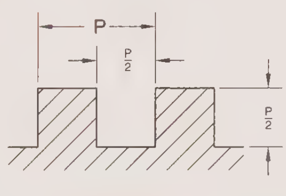
FORM	USE	EXAMPLE
UNIFIED	FASTENING	1
	ADJUSTING	2
KNUCKLE	LOOSE FASTENING	3
SQUARE	TRANSMITTING POWER	4
ACME	TRANSMITTING POWER	5
BUTTRESS	TRANSMITTING POWER IN ONE DIRECTION ONLY	6



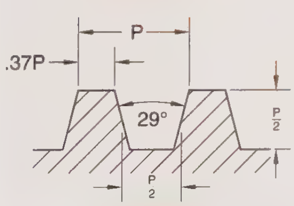
UNIFIED



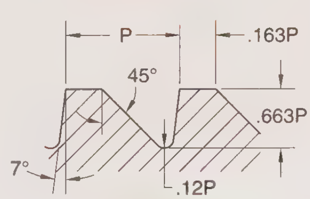
KNUCKLE



SQUARE



ACME



BUTTRESS

Figure 5-3. Thread forms may be unified, knuckle, square, acme, or buttress.

Complete (full) thread. The part of the thread having full form at both crest and root. When there is a chamfer at the start of the thread not exceeding two pitches in length, it is included within the length of complete thread.

Incomplete (vanish or washout) thread. On straight threads, the portion at the end having roots not fully formed by the lead or chamfer on threading tools.

Blunt start. The removal of the partial thread at the entering end of the thread. This is a feature of threaded parts which are repeatedly assembled by hand, such as hose couplings and thread plug gauges, to prevent cutting of hands and crossing of threads.

Terms For Dimensions of Screw Threads

The dimensions of screw threads are based on the pitch and the diameter. Pitch determines the number of threads per inch. The diameter determines the width of the threaded form. Refer to Figure 5-3.

Pitch. The distance, measured parallel to the thread's axis, between corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis.

Lead. The distance a threaded part moves axially, with respect to a fixed mating part, in one complete rotation.

Threads per inch. The reciprocal of the pitch in inches.

Included angle (angle of thread). The angle between the flanks of the thread measured in an axial plane.

Major diameter. On a straight thread, the diameter of the imaginary co-axial cylinder which bounds the crest of an external thread or the root of an internal thread. On a taper thread at a given position on the thread axis, the diameter of the major cone.

Minor diameter. On a straight thread, the diameter of the imaginary co-axial cylinder which bounds the root of an external thread or the crest of an internal thread. On a taper thread at a given position on the thread axis, the diameter of the minor cone at that position.

Pitch diameter (simple effective diameter). On a straight thread, the diameter of the imaginary co-axial cylinder, the surface of which would pass through the thread profiles at such points as to make the width of the groove equal to one-half of the basic pitch. On a taper thread at a given position on the thread axis, the diameter of the pitch cone at that position.

Length of thread engagement. The distance between the extreme points of contact on the pitch cylinders or cones of two mating threads measured parallel to the axis.

Crest clearance. In a thread assembly, the distance, measured perpendicular to the axis, between the crest of a thread and the root of its mating thread.

Development of Threaded Fasteners

Early threaded fasteners were not uniform in size or thread profile and consequently were not interchangeable. The need for interchangeable parts prompted the work of Sir Joseph Whitworth of Great Britain and William Sellers of the United States. In the nineteenth century, Whitworth developed the Whitworth Thread, which had a standard thread angle of approximately 55°, and Sellers developed the basis for the American National thread, which had a standard thread angle of 60°.

The Unified Screw Thread Standard was developed by committees from the United States, Great Britain, and Canada based on the 60° standard thread angle. Subsequent developments led to the Unified Inch Screw Thread (UN and UNR Thread Form). Profiles of UN (Unified National) and UNR (Unified National Rounded) threads are the same, except that roots and crests of UNR threads may be rounded. Additionally, the basic profile of UN and UNR threads is the same as ISO (International Organization for Standardization) metric threads, except for the diameter and number of threads per inch. See Figure 5-4. See Appendix.

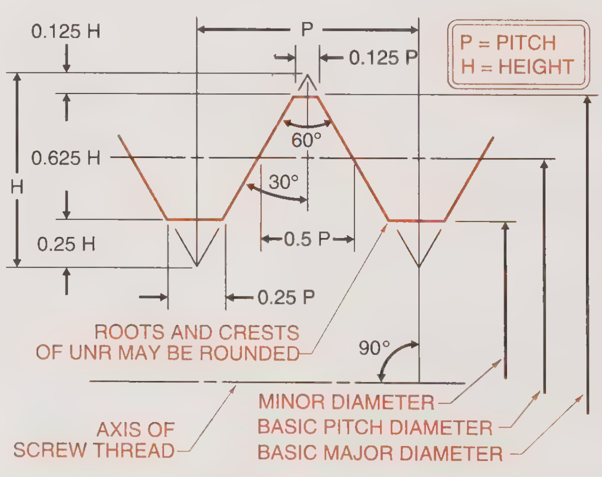


Figure 5-4. The basic profiles of UN and UNR threads are the same.

Screw Thread Series

Screw thread series are groups of diameter-pitch combinations. Screw thread series are distinguished from one another by the number of threads per inch for a series of specific diameters. For example, the *standard series* is a screw thread series of coarse (UNC/UNRC), fine (UNF/UNRF), and extra-fine (UNEF/UNREF) graded pitches and eight series with constant pitches. See Figure 5-5.

Graded pitch is a standard screw thread series with a different number of threads per inch based on the diameter. Generally, the smaller the diameter of the graded pitch series, the larger the number of threads per inch. For example, a 2 (0.0860″) UNC thread has 56 threads per inch while a ¾ (0.7500″) UNC thread has 10 threads per inch.

Constant pitch is a standard screw thread series with a set number of threads per inch regardless of diameter. Constant pitch series may have 4, 6, 8, 12, 16, 20, 28, or 32 threads per inch. The larger the diameter, the smaller the number of threads per inch. For example, a 2½ diameter bolt has 4, 6, 8, 12, 16, or 20 threads per inch, while a ¼ diameter bolt has 20, 28, or 32 threads per inch.

The *special series* is a screw thread series with combinations of diameter and pitch not in the standard screw thread series. Preference is given to standard series coarse and fine graded pitch threads.

Threads are grouped into series by their pitch. Pitch is the distance between corresponding points on adjacent thread forms. Pitch is always measured parallel to the axis. To find pitch, apply the formula:

STANDARD SERIES THREADS – GRADED PITCHES						
NOMINAL DIAMETER	UNC		UNF		UNEF	
	TPI	TAP DRILL	TPI	TAP DRILL	TPI	TAP DRILL
0 (.0600)			80	3/64		
1 (.0730)	64	No. 53	72	No. 53		
2 (.0860)	56	No. 50	64	No. 50		
3 (.0990)	48	No. 47	56	No. 45		
4 (.1120)	40	No. 43	48	No. 42		
5 (.1250)	40	No. 38	44	No. 37		
6 (.1380)	32	No. 36	40	No. 33		
8 (.1640)	32	No. 29	36	No. 29		
10 (.1900)	24	No. 25	32	No. 21		
12 (.2160)	24	No. 16	28	No. 14	32	No. 13
1/4 (.2500)	20	No. 7	28	No. 3	32	7/32
5/16 (.3125)	18	F	24	I	32	9/32
3/8 (.3750)	16	5/16	24	Q	32	11/32
7/16 (.4375)	14	U	20	25/64	28	13/32
1/2 (.5000)	13	27/64	20	29/64	28	15/32
9/16 (.5625)	12	31/64	18	33/64	24	33/64
5/8 (.6250)	11	17/32	18	37/64	24	37/64
11/16 (.6875)					24	41/64
3/4 (.7500)	10	21/32	16	11/18	20	45/64
13/16 (.8125)					20	49/64
7/8 (.8750)	9	49/64	14	13/16	20	53/64
15/16 (.9375)					20	57/64
1 (1.000)	8	7/8	12	59/64	20	61/64

Figure 5-5. Screw threads series are groups of diameter-pitch combinations.

$$P = \frac{1''}{N/in.}$$

where

P = pitch

$1''$ = constant

$N/in.$ = threads per inch

For example, what is the pitch of a thread form having 16 threads per inch?

$$P = \frac{1''}{N/in.}$$

$P = 1/16$

$P = 1/16''$

Metric threads are measured in millimeters (25.4 mm = 1″). The same basic formula can be used to determine the approximate pitch for metric threads. Threads may be either graded pitch or constant pitch.

Screw Thread Classes

The class of thread indicates its tolerance and allowance. *Tolerance* is the amount of variation allowed above or below a dimension. *Allowance* is the difference between the design size and the basic size of a thread. The screw thread classes have been developed for the thread forms.

Unified Threads. Threaded classes in the Unified Standard are designated by a numeral followed by the letter A for external threads and B for internal threads. The three classes of external threads are 1A, 2A, and 3A. The three classes of internal threads are 1B, 2B, and 3B.

Classes 1A and 1B have the greatest amount of allowance. They are intended for applications that require frequent and rapid assembly and disassembly with minimum binding even with slightly bruised or dirty threads.

Classes 2A and 2B are considered standard for general purpose threads on bolts, nuts, and screws. They provide standard allowances to ensure minimum clearance between external and internal threads which minimize galling and seizing in high-cycle wrench assembly. Because of their realistic tolerances, classes 2A and 2B are widely used for mass production purposes.

Classes 3A and 3B are suitable for applications requiring closer tolerances than those provided by classes 2A and 2B. They are designated for set screws, socket head cap screws, aircraft bolts, and for higher strength materials where it is necessary to limit the variations of the thread elements.

The requirements for screw thread fits depend on their end use. Combination of thread classes for components is possible. For example, a Class 2A external thread may be used with a Class 1B, 2B, or 3B internal thread. Cost generally increases proportionately to the accuracy required. For economy, no closer thread fit should be used than is needed for the proper functioning of the components.

Acme Threads. The American National Standards Institute (ANSI) lists two types of Acme threads, the General Purpose (G) and the Centralizing (C). The General Purpose threads have three classes: 2G, 3G, and 4G. The classes designated as G provide ample fits for free movement of threaded parts. Centralizing threads have five classes: 2C, 3C, 4C, 5C, and 6C. These threads have limited clearance on major diameters in order to maintain proper alignment of the thread axes.

Buttress Threads. Three classes have been standardized for buttress threads: Class 1 (Free), Class 2 (Medium), and Class 3 (Close).

Screw Thread Designation

Threads are designated by thread notes. The thread note specifies in sequence the nominal size, number of threads per inch, thread form and series, and thread class. For example, the thread note ½-13 UNC-2A specifies ½″ nominal diameter, 13 threads per inch, Unified National Coarse thread form, Class 2 fit, and external thread.

The nominal size of the diameter may be stated in fractional or decimal dimensions. The letters LH follow the thread note for left-hand threads. If not specified, the thread is a right-hand thread. The length of threaded fasteners is often included at the end of the thread note. See Figure 5-6.

Thread Representation

Thread representation is the method of drawing used to show a threaded part. Screw threads are represented on drawings by three methods: simplified representation, schematic representation, and detailed representation. See Figure 5-7.

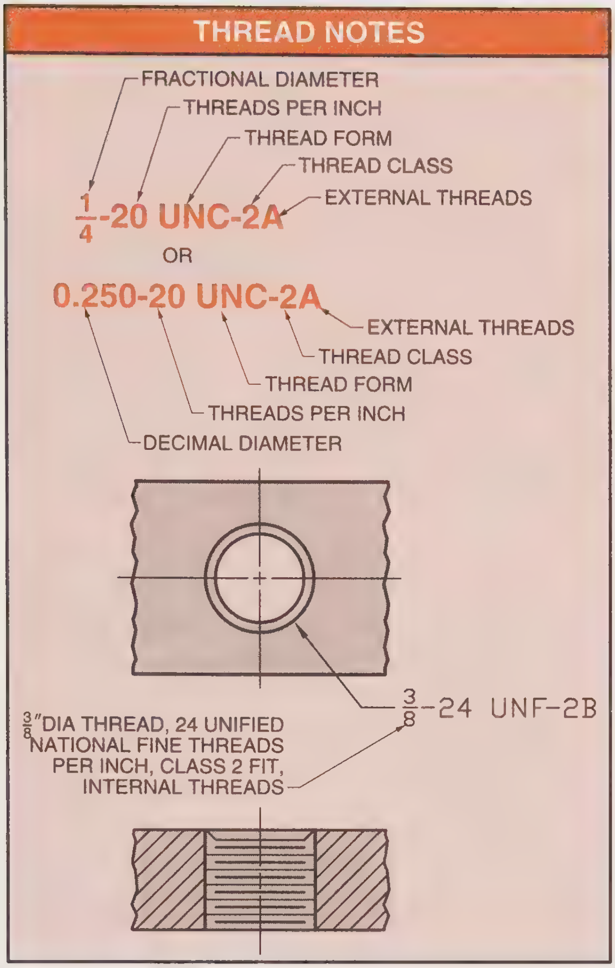


Figure 5-6. Threads are designated by thread notes.

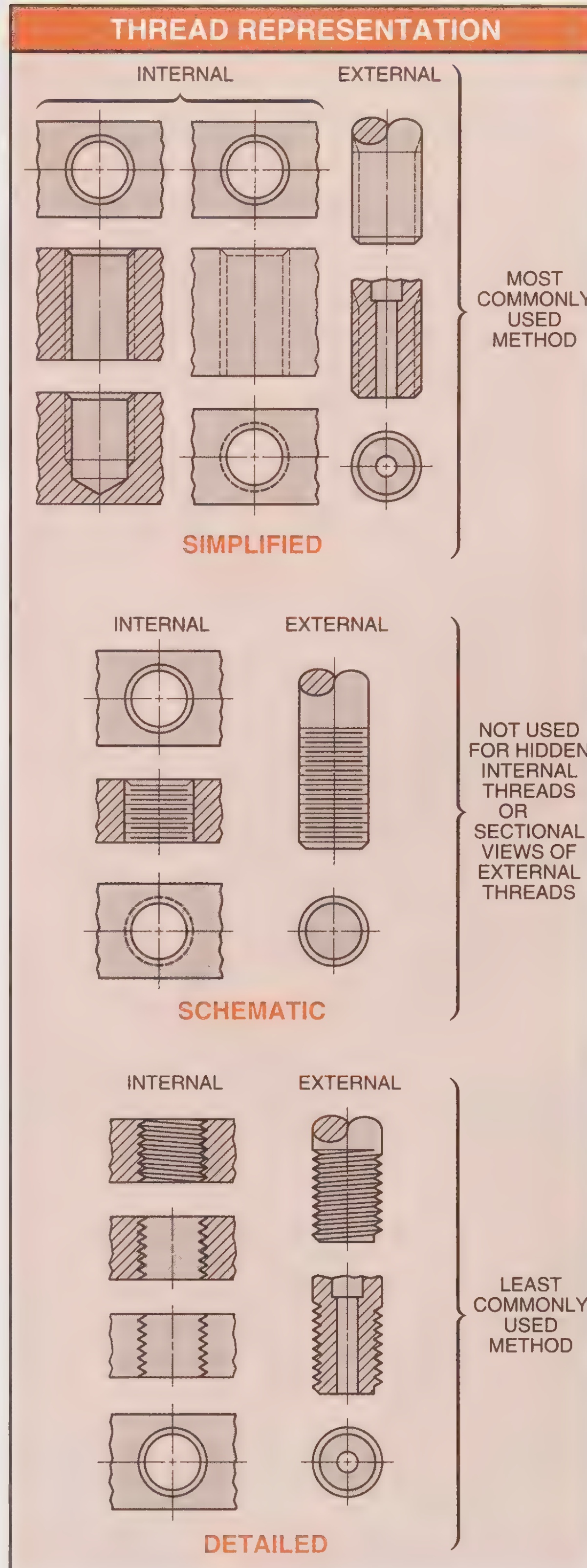


Figure 5-7. Thread representation is the method of drawing used to show a threaded part.

Simplified Representation. *Simplified representation* is a method of thread representation in which hidden lines are drawn parallel to the axis at the approximate depth of the thread. Simplified representation is the most commonly used method of thread representation. Various combinations of internal, external, and sectional views of threads are shown with this method.

Schematic Representation. *Schematic representation* is a method of thread representation in which solid lines perpendicular to the axis represent roots and crests. This method is not used for hidden internal threads or sectional views of external threads.

Detailed Representation. *Detailed representation* is a method of thread representation in which the thread profiles are connected by helices. A helix is the curve formed by a line angular to the axis of a cylinder and in a plane wrapped

around the cylinder. Detailed representation is the least commonly used method of thread representation because it is time-consuming to draw.

Thread Representation Conventions. One method of thread representation is commonly used throughout one drawing, although more than one method may be used on the same drawing for clarity. End purpose and use of drawings, drafting time, etc., influence the selection and use of the conventions. For clarity of meaning where good judgment dictates, all three conventions may be used on a single drawing. See Figure 5-8.

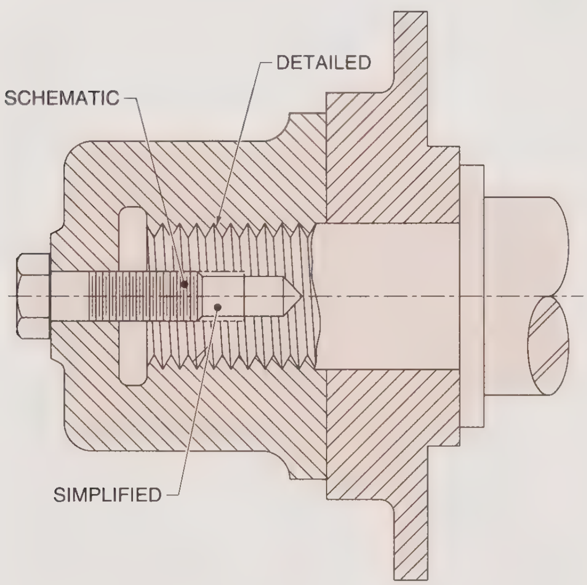


Figure 5-8. Simplified, schematic, and detailed thread representation conventions may be used on a single drawing.

Bolts, Screws, and Nuts

Bolts, screws, and nuts are purchased parts. Consequently, they are generally shown on prints as thread representations with notes giving specific information. Bolts and screws are available in a wide range of sizes (diameters and lengths), hardnesses, head styles, etc. See Figure 5-9.

The length of a bolt or screw is the distance from the bearing surface of the head to the tip, measured parallel to the axis. The thread length for standard bolts is generally twice the diameter plus ¼″ for bolts up to 6″. For bolts over 6″, the thread length is generally twice the diameter plus ½″.

Nuts are either square (four sides) or hexagonal (six sides). Their distance across flats corresponds with standard English or metric dimensions to facilitate driving with wrenches, and sockets and ratchets.

Washers

The three basic types of washers are plain, spring lock, and tooth lock. All three types are available in standard sizes for use with standard bolts and screws.

Plain Washers. Plain washers are round and flat. They are used under the head of a screw or bolt, or under a nut to spread a load over a greater area. They are also used to prevent the marring of the parts during assembly as a result of the turning of the screw, bolt, or nut. See Figure 5-10.

Spring Lock Washers. Spring lock washers are split on one side and are helical in shape. They are made of steel that is capable of being hardened or of bronze or aluminum alloys.

Spring lock washers have the dual function of: (1) springing take-up devices to compensate for developed looseness and the loss of tension between component parts of an assembly, and (2) acting as hardened thrust bearings to facilitate assembly and disassembly of bolted fastenings by decreasing the frictional resistance between the bolted surface and the bearing face of the bolt head or nut. See Figure 5-11.

Tooth Lock Washers. Tooth lock washers are external, internal, internal-external, or countersunk external. See Figure 5-12. The hardened teeth of these washers are twisted offset to bite or grip both the bolt head or the nut and the respective work surface to help prevent the loosening of the assembly due to vibration. They also make good electrical contacts. Unlike spring lock washers, they do not provide spring action to counteract wear or stretch in the parts of an assembly.

The external tooth lock washer is the most commonly used of the tooth lock washers, but the internal tooth lock washer is generally used where it is necessary to consider appearance and to insure engagement of teeth with the bearing surface of the fastener.

Where additional locking ability is required or where there is need for a large bearing surface, such as over a clearance hole, the internal-external tooth lock washer may be used. Countersunk external tooth lock washers are used with flat head and oval head machine screws.

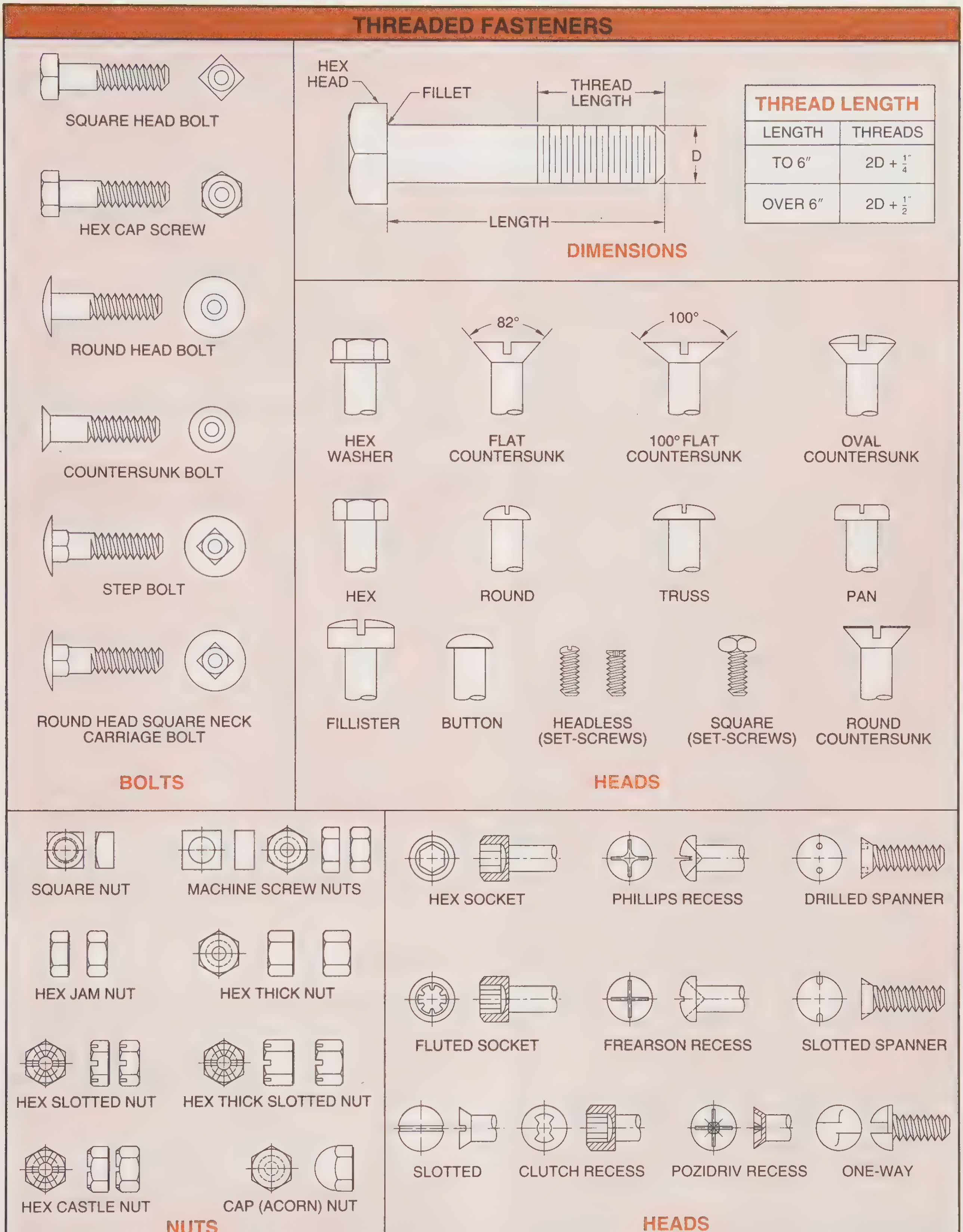
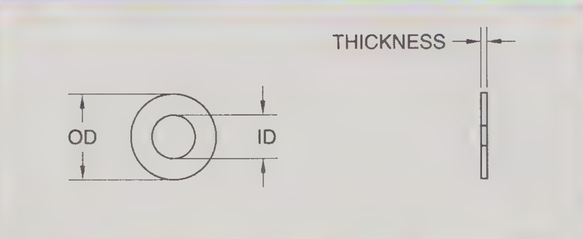


Figure 5-9. Bolts, screws, and nuts are threaded fasteners.

FLAT WASHERS



TYPE	BOLT SIZE	ID	OD	THICKNESS
ZINC	1/4	5/16	3/4	1/16
	5/16	3/8	7/8	5/64
	3/8	7/16	1	5/64
	7/16	1/2	1 1/4	5/64
	1/2	9/16	1 3/8	7/64
	5/8	11/16	1 3/4	9/64
	3/4	13/16	2	5/32
	7/8	15/16	2 1/4	11/64
	1	1 1/16	2 1/2	11/64
STAINLESS STEEL	#4	0.125	0.312	0.031
	#6	0.149	0.375	0.031
	#8	0.174	0.375	0.031
	#10	0.203	0.437	0.031
	1/4	9/32	5/8	0.050
	5/16	11/32	3/4	0.050
	3/8	13/32	7/8	0.050
	1/2	17/32	1 1/4	0.062
	5/8	11/16	1 1/2	0.078
SAE ZINC	#8	3/16	1/2	3/64
	#10	7/32	1/2	3/64
	1/4	9/32	5/8	1/16
	5/16	11/32	11/16	1/16
	3/8	13/32	13/16	1/16
	7/16	15/32	59/64	1/16
	1/2	17/32	1 1/16	3/32
	9/16	19/32	1 5/32	3/32
	5/8	21/32	1 5/16	3/32
	3/4	13/16	1 1/2	9/64
	7/8	15/16	1 3/4	9/64
	1	1 1/16	2	9/64
FENDER	3/16	17/64	1	3/64
	1/4	17/64	1	3/64
	1/4	9/32	1 1/4	3/64
	1/4	9/32	1 1/2	3/64
	5/16	11/32	1 1/4	3/64
	5/16	11/32	1 1/2	3/64
	3/8	13/32	1 1/4	3/64
	3/8	13/32	1 1/2	3/64
	1/2	17/32	2	3/64
SAE GRADE 8 ZINC	1/4	9/32	5/8	1/16
	5/16	11/32	11/16	1/16
	3/8	13/32	13/16	1/16
	7/16	15/32	59/64	1/16
	1/2	17/32	1 1/16	3/32
	5/8	21/32	1 5/16	3/32
	3/4	13/16	1 1/2	9/64
	7/8	15/16	1 3/4	9/64
	1	1 1/16	2	9/64

Figure 5-10. Plain washers are round and flat.

SPRING LOCK WASHERS

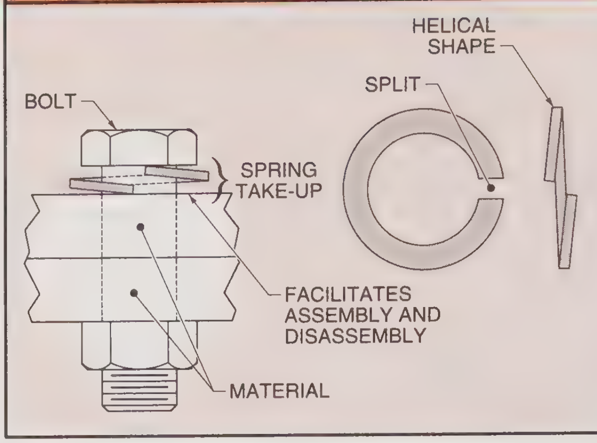


Figure 5-11. Spring lock washers are split and helical in shape.

TOOTH LOCK WASHERS

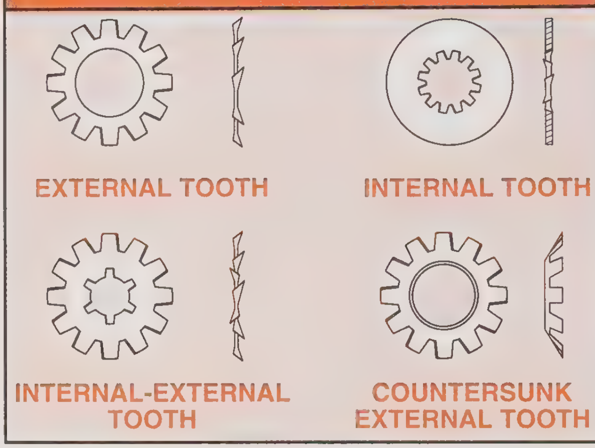


Figure 5-12. Various types of tooth lock washers have teeth that are offset to bite or grip the bolt or nut and the work surface.

Pipe Threads

The two standard forms of pipe threads are regular and dryseal. Regular pipe thread is the standard for the plumbing trade. Dryseal pipe thread is the standard for automotive, refrigeration and hydraulic tube and pipe fittings, lubrication fittings, and drain cocks.

Regular pipe thread forms allow crest and root clearance when the flanks contact. Leakage occurs if this clearance is not filled. With dryseal pipe thread forms, there is no crest and root clearance and sealer is not needed.

Regular and dryseal threads come in two forms, straight and tapered. The tapered thread insures a tighter joint. Regular threads are designated as NPS (straight) and NPT (tapered). Dryseal threads are identified as NPSF (straight) and NPTF (tapered).

Pipe threads should be shown on a drawing by means of the simplified method. The taper threads are drawn the same as the straight threads except that the thread lines should form an angle of approximately 3° with the axis. The designation of pipe threads on a drawing should include the nominal size, number of threads per inch, thread form, and thread series symbols. For example, the thread note $\frac{1}{8}$-27 Dryseal NPTF specifies $\frac{1}{8}''$ ID pipe, 27 threads per inch, Dryseal thread form, and American National Standard Taper Pipe thread series. See Figure 5-13.

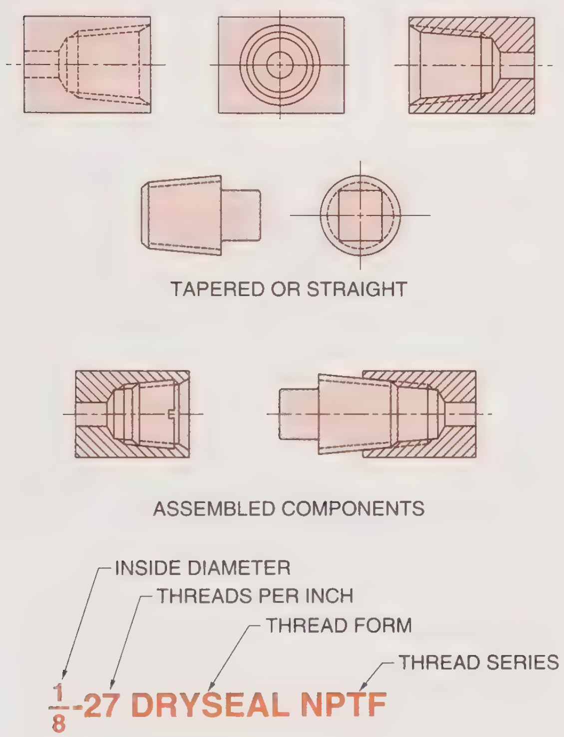


Figure 5-13. Pipe thread is shown on a drawing by the conventional simplified representation.

NONTHREADED FASTENERS

Nonthreaded fasteners are devices that join or fasten parts together without threads. The most common nonthreaded fastener is the rivet. A *rivet* is a cylindrical metal pin with a preformed head. The rivet shank is inserted through holes and pressed or beaten into a second head to hold the parts together. The *shank* is the cylindrical body of a rivet. The riveting process can also be automated. The shape of the preformed head and the length and diameter of the shank distinguish one rivet from another.

Two parts are joined together by the grip of a rivet which fits through predrilled holes slightly larger than the shank of the rivet. The length of the shank must exceed the thickness of the two parts to be joined by enough material to allow the shank to be upset or shaped into the final form. The *grip* is the effective holding length of a rivet. The size of the rivet required is determined by the thickness of the parts being joined. See Figure 5-14.

Rivets are relatively inexpensive and are generally manufactured from ductile metals such as steel, aluminum, copper, brass, and bronze. A *ductile* metal is a metal that can be formed easily. Riveting can also be used to join materials that cannot be welded, such as dissimilar metals, plastics, or materials which could be damaged by heat.

A riveted joint is permanent. However, rivets can loosen under stress and become ineffective. Rivets are also subject to corrosion by liquids and generally cannot hold pressure because of the possibility of leaks.

Rivets are classified into three groups: large, small, and blind. *Large rivets* are rivets with a shank of $\frac{1}{2}''$ or greater in diameter. The second head of large rivets can only be formed by applying force to the rivet after it has been heated red hot. *Small rivets* are rivets with a shank of $\frac{7}{16}''$ or less in diameter. *Blind rivets* are rivets with a hollow shank that join two parts with access from one side only.

Rivets are shown on prints with conventional representation. Shop rivets are shown as clear circles with slash marks indicating countersinking, flattening, near side, far side, and both sides. *Shop rivets* are rivets placed in the shop. Field rivets are shown as darkened circles with slash marks indicating countersinking, flattening, near side, far side, and both sides. *Field rivets* are rivets placed in the field.

Rivet placement is controlled by the thickness of the material being riveted, pitch, and margin. *Rivet pitch* is the distance from the center of one rivet to the center of the next rivet in the same row.

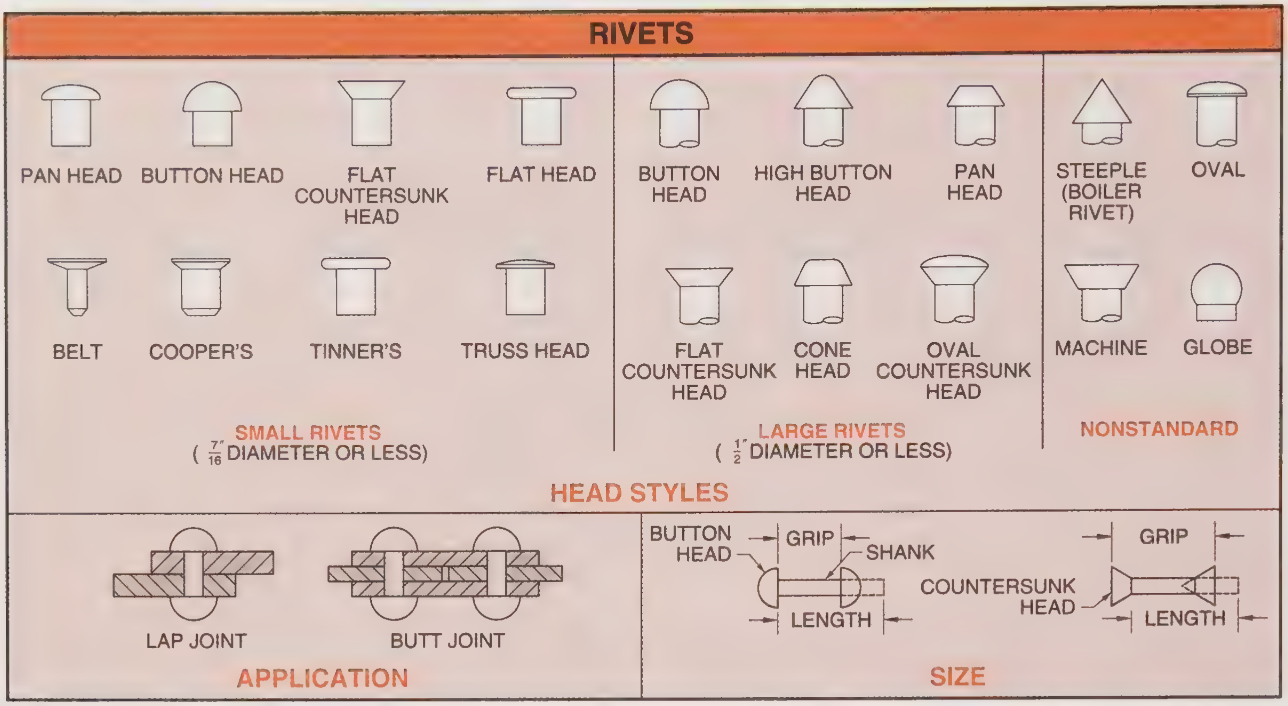


Figure 5-14. Rivets are nonthreaded fasteners used to join or fasten parts.

Back (transverse) pitch is the distance from the center of one row of rivets to the center of the adjacent row of rivets. *Diagonal pitch* is the distance between the centers of rivets nearest each other in adjacent rows. *Margin* is the distance from the edge of the plate to the center line of the nearest row of rivets. See Figure 5-15.

Pins

Pins are cylindrical, nonthreaded fasteners that are placed into a hole to secure the position of two or more parts. A wide variety of pin types, sizes, and materials are commercially available. Standard pins include straight, dowel, tapered, clevis, cotter, slotted spring, spirally coiled, and grooved. See Appendix for dimension tables for pin types shown in Figures 5-16 through 5-23.

Straight Pins. Straight pins are usually fabricated from bar stock. The ends are either square or chamfered. They are often used to transmit torque in round shafts. See Figure 5-16.

Dowel Pins. Dowel pins are fabricated from bar stock. Hardened dowel pins are bullet-nosed on the entry end. Soft dowel pins are chamfered on both ends. Dowel pins are used in machine and tool fabrication. See Figure 5-17.

Tapered Pins. Tapered pins are fabricated from bar stock. To find the small diameter of a tapered pin, multiply the length by 0.2083 and subtract from the large diameter. The ends are rounded. Tapered pins are used to transmit small torques or to position parts. See Figure 5-18.

Clevis Pins. Clevis pins are fabricated from bar stock. The heads are radiused and the entry ends have broken corners. They are used to attach clevises to rod ends and levers and to serve as bearings. Clevis pins are held in place by cotter pins. See Figure 5-19.

Cotter Pins. Cotter pins are used with clevis pins to prevent the clevis pin from becoming disengaged. The entry ends are opened after insertion to keep the cotter pins in place. See Figure 5-20.

Slotted Spring Pins. Slotted spring pins are tubular with one longitudinal slot. The ends are chamfered and the pins are self-locking. See Figure 5-21.

Spirally Coiled Pins. Spirally coiled pins are rolled from spring stock. The entry ends have a swaged chamfer. The spring stock compresses upon entry and expands to hold firmly. See Figure 5-22.

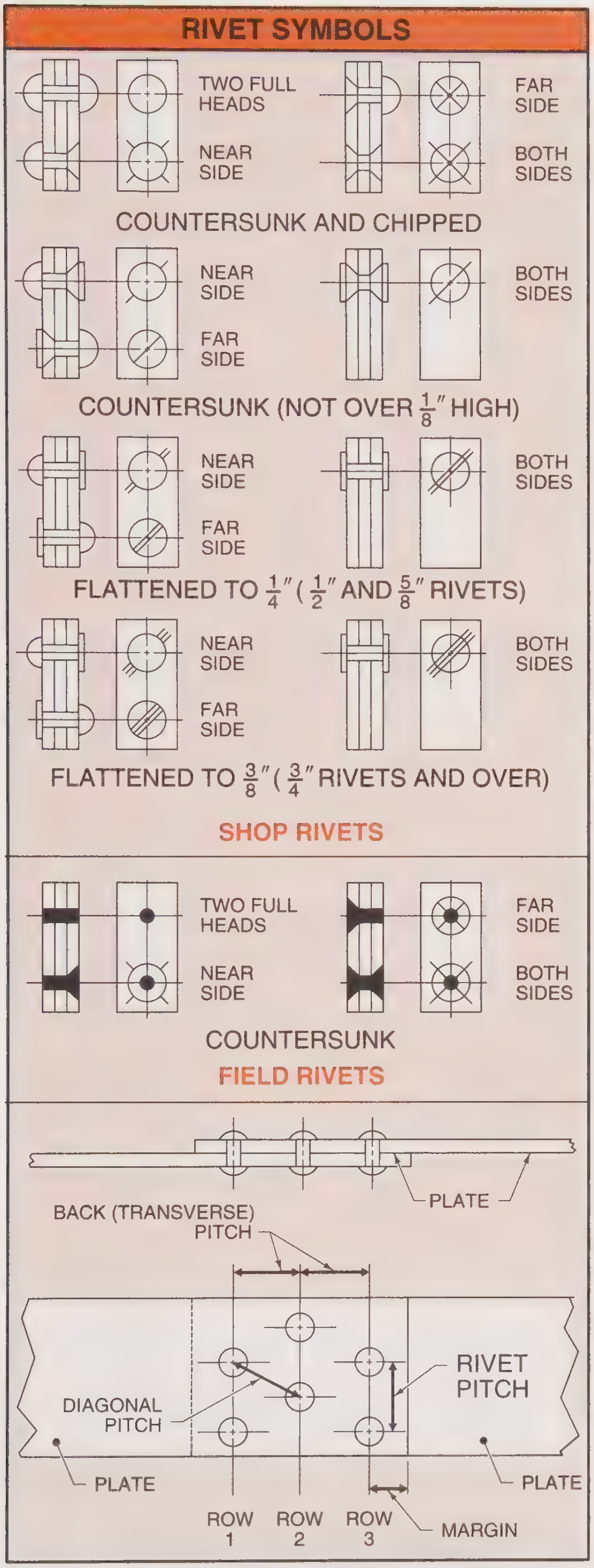


Figure 5-15. Conventional rivet symbols are used to show rivets on prints.

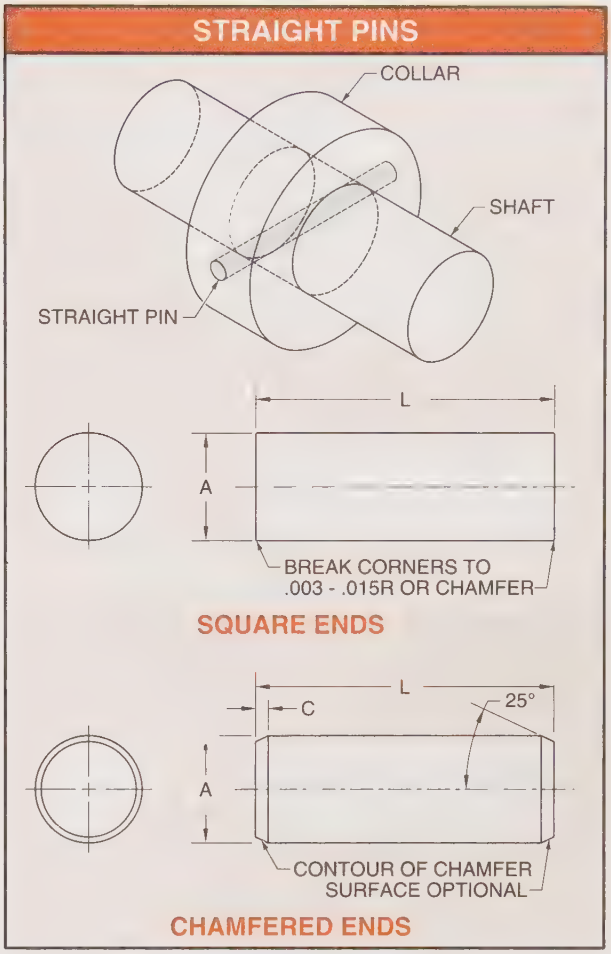


Figure 5-16. Straight pins are fabricated from bar stock and have square or chamfered ends.

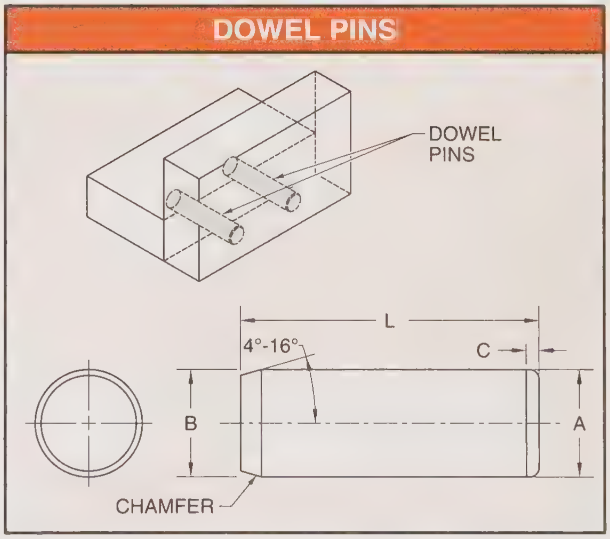


Figure 5-17. Dowel pins are fabricated from bar stock and are bullet-nosed or have chamfered ends.

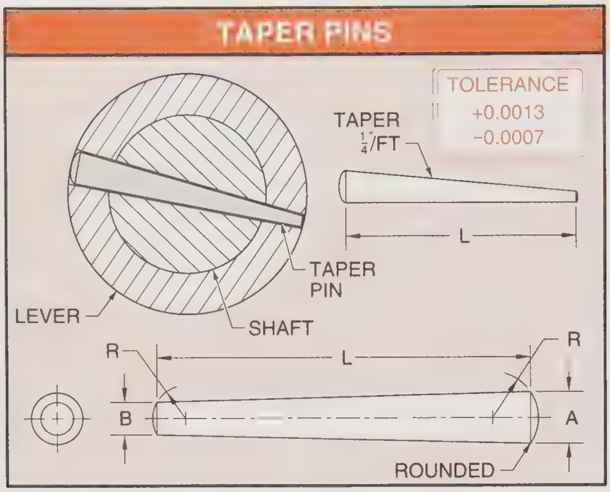


Figure 5-18. Taper pins are fabricated from bar stock and have rounded ends.

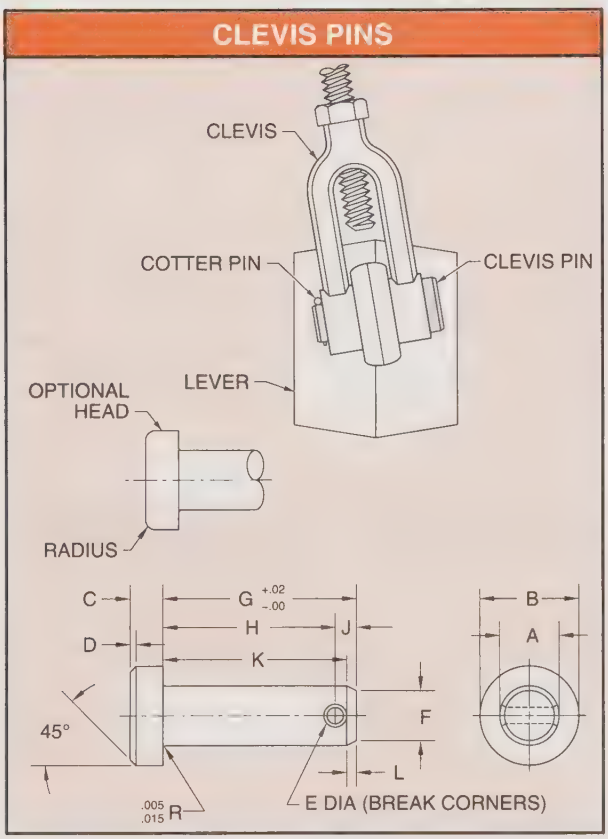


Figure 5-19. Clevis pins are fabricated from bar stock with a head on one end and broken corners on the entry end.

Grooved Pins. Grooved pins are solid with three parallel, equally spaced grooves. The grooves provide a tight fit and a locking feature. They are used for semi-permanent fastening of levers, collars, gears, cams, etc., to shafts. See Figure 5-23.

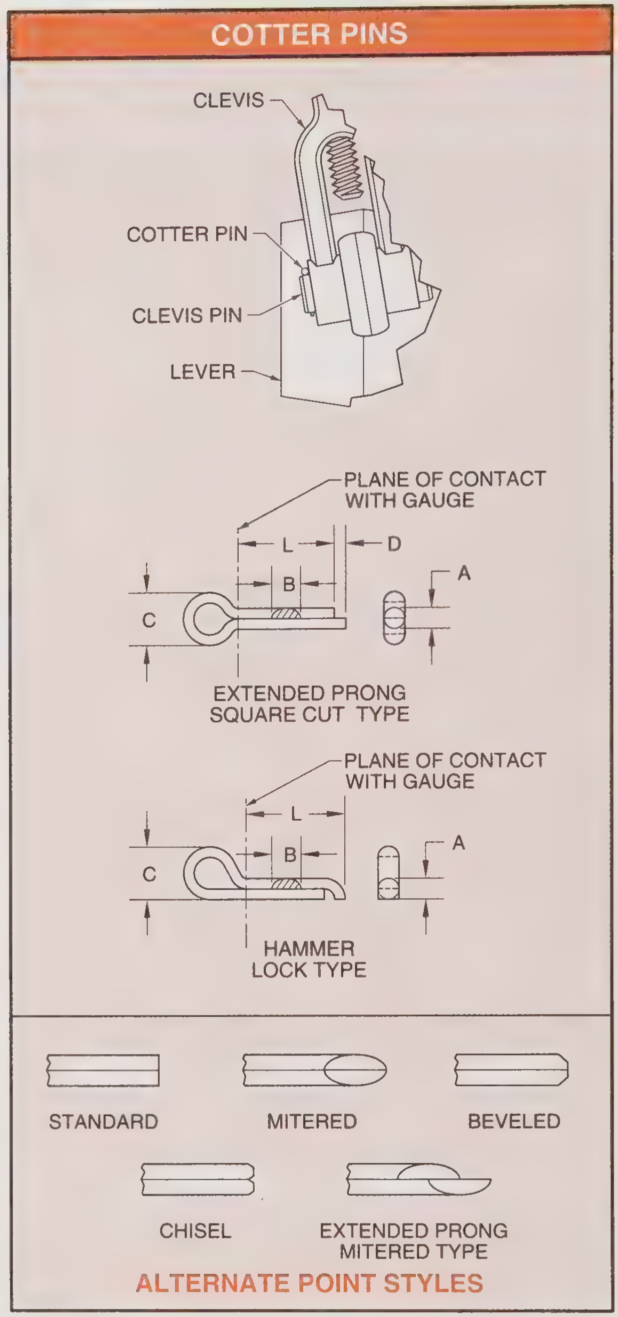


Figure 5-20. Cotter pins are used with clevis pins.

Keys

Keys are removable parts which provide a positive means of transmitting torque between a shaft and a hub when mounted in a keyseat. A *keyseat* is a rectangular groove along the axis of a shaft or hub.

The basic shapes of keys include parallel, taper, and Woodruff. All are available in stock sizes in English and Metric measurement systems. See Figure 5-24. See Appendix.

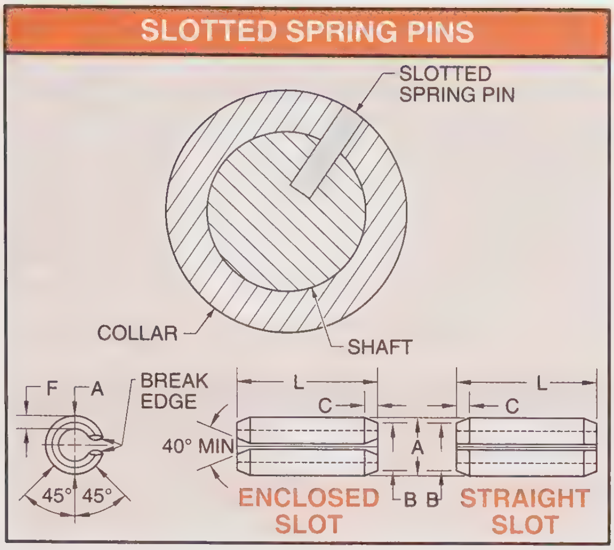


Figure 5-21. Slotted spring pins are tubular with one elongated slot.

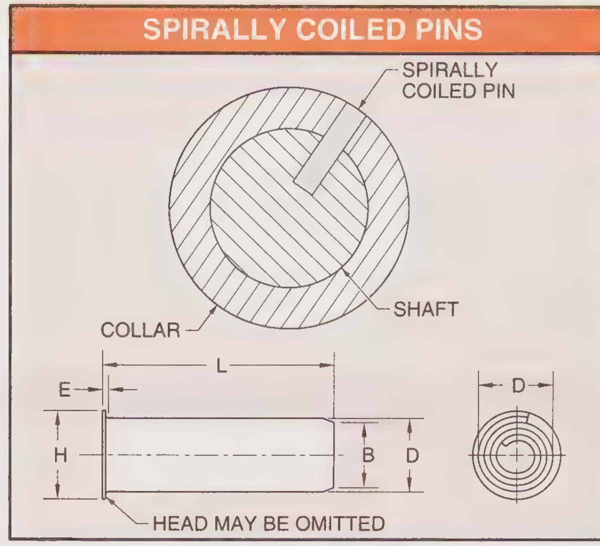


Figure 5-22. Spirally coiled pins are rolled from spring stock.

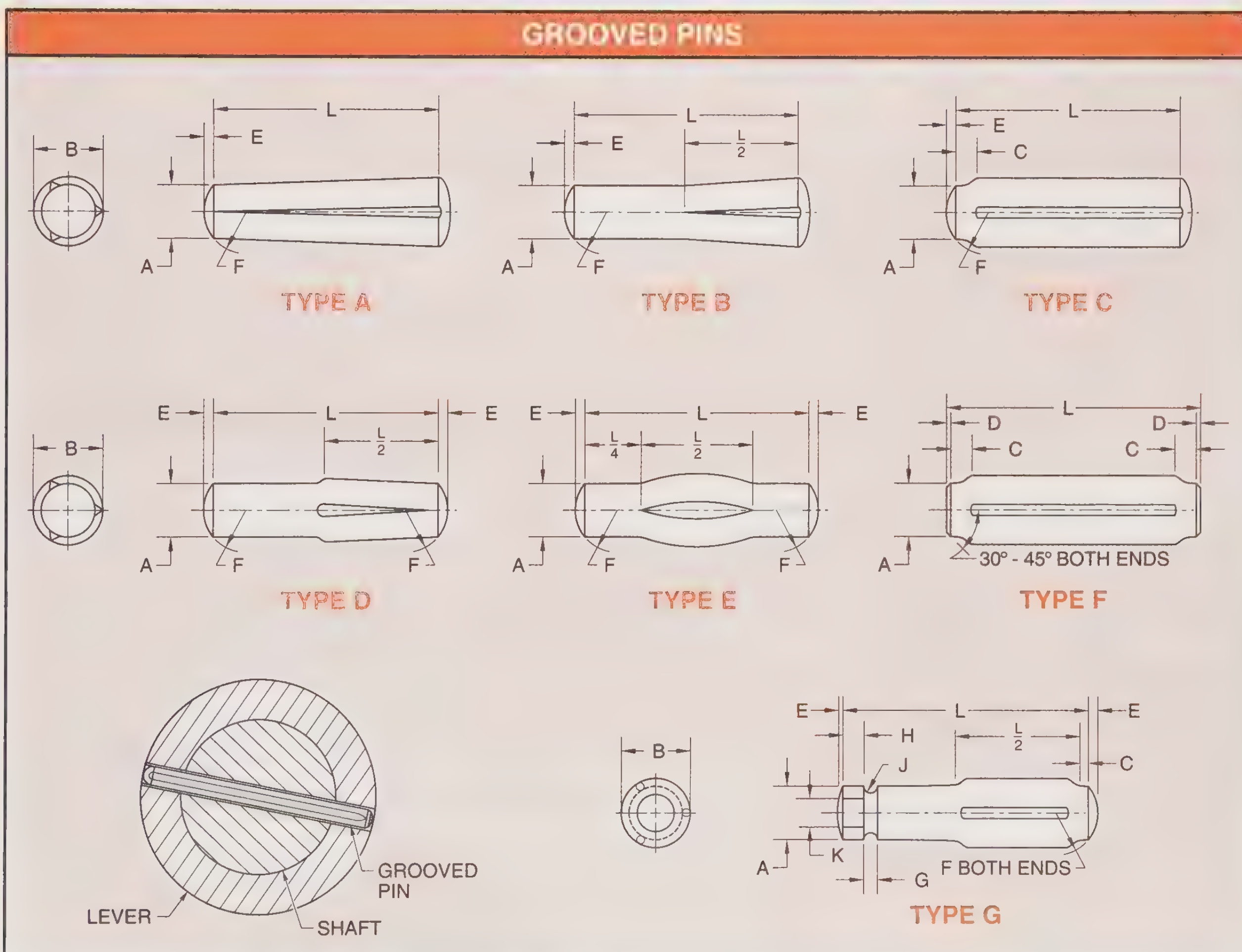


Figure 5-23. Grooved pins are fabricated from bar stock and have three parallel, equally spaced grooves.

Parallel keys are square or rectangular in shape. They are used for transmitting unidirectional torques in shafts and hubs which do not have heavy starting loads. Parallel keys may be easily withdrawn.

Taper keys may be either plain taper, alternate plain taper, or gib head taper. They are used for transmitting heavy unidirectional torques in shafts and hubs which are reversed frequently and subject to vibration. Taper keys may be easily withdrawn.

Woodruff keys are half-moon in shape. They may have a full radius or flat bottom. Woodruff keys are used for transmitting light torques or locating parts on tapered shafts. The key numbers indicate nominal dimensions. The last two digits give the nominal diameter in eighths of an inch. The digits in front of the last two digits give the nominal width in thirty-seconds of an inch. For example, a #204 Woodruff key is ½″ in nominal diameter and $\frac{1}{16}$″ in width.

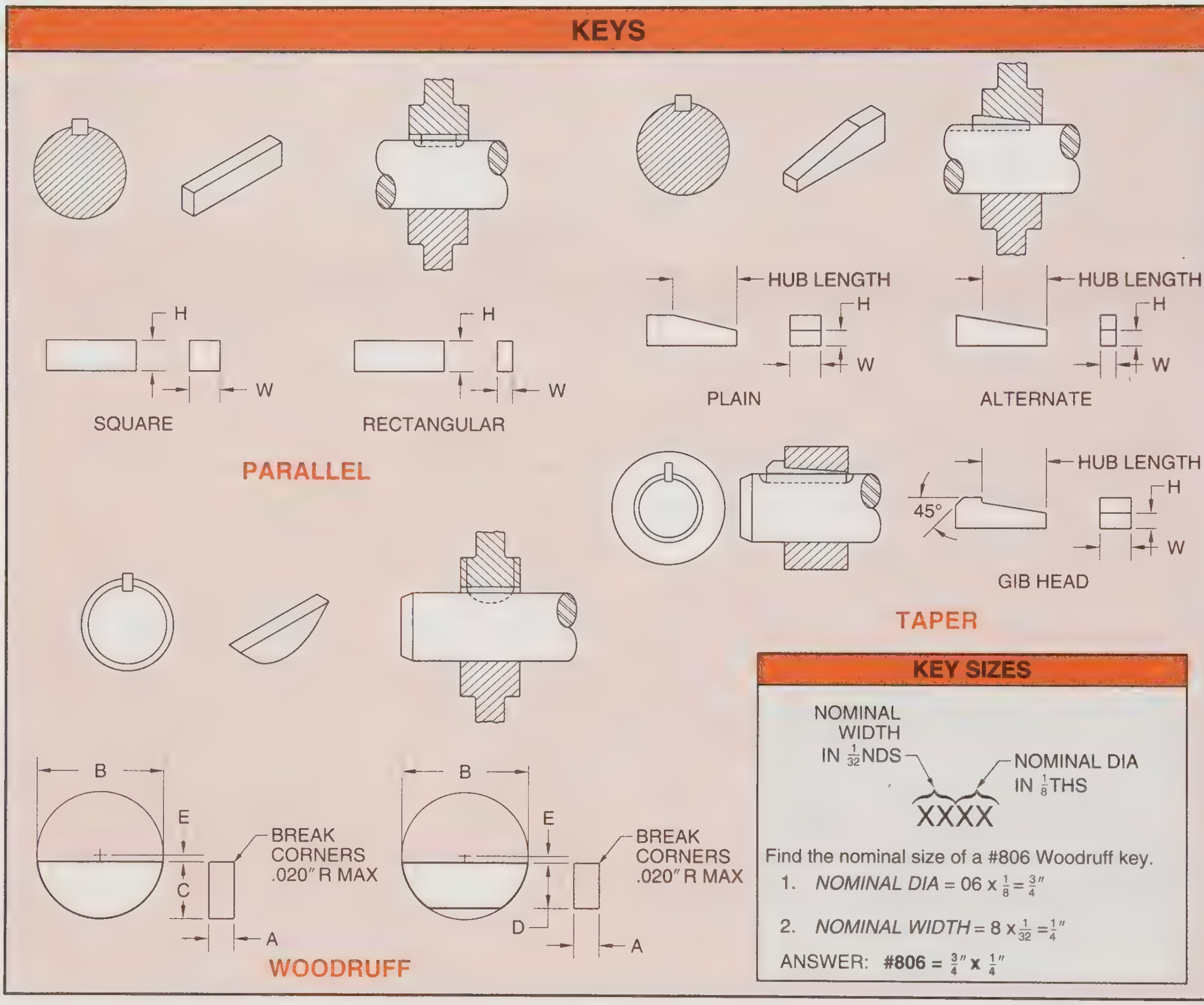


Figure 5-24. The basic shapes of keys include parallel, taper, and Woodruff.

Ø6 A1

Review Questions

Name ______________________________ Date ______________

Completion

_________ 1. The length of a bolt or screw is the distance from the bearing surface of the head to the tip, measured parallel to the _________.

_________ 2. Rivet _________ is the effective holding length of a rivet.

_________ 3. Thread _________ is the method of drawing used to show a threaded part.

_________ 4. _________ rivets have a hollow shank that join two parts with access from one side only.

_________ 5. _________ washers are round and flat.

_________ 6. Back pitch is also known as _________ pitch.

_________ 7. _________ is the distance between corresponding points on adjacent thread forms.

_________ 8. _________ is the distance from the edge of the plate to the center line of the nearest row of rivets.

_________ 9. Screw thread _________ are groups of diameter-pitch combinations.

_________ 10. _________ pitch is a standard screw thread series with a different number of threads per inch based on the diameter.

_________ 11. Threaded fasteners are based upon an inclined _________ wrapped around a cylinder.

_________ 12. The thread length of a standard bolt with a 3/8″ diameter and a 3″ length is _________″.

_________ 13. UN threads are based on a(n) _________° thread angle.

_________ 14. The pitch of a thread form having 20 threads per inch is _________″.

_________ 15. A(n) _________ designates an external thread.

_________ 16. The size of the rivet required is determined by the _________ of the parts being joined.

_________ 17. _________ are removable parts which provide a positive means of transmitting torque between a shaft and a hub.

_________ 18. Hardened dowel pins are _________ on the entry end.

_________ 19. _________ are cylindrical, nonthreaded fasteners that are placed into a hole to secure the position of two or more parts.

_________ 20. Rivets generally cannot hold _________.

_________ 21. _________ pins are used with clevis pins to prevent the clevis pin from becoming disengaged.

__________ 22. __________ keys are half-moon in shape.

__________ 23. A right-hand thread always slopes up to the __________ regardless of the position it occupies on the drawing.

__________ 24. A(n) __________ is the curve traced on a cylinder or cone by a point rotating at a right angle to the axis.

__________ 25. In a single thread, the lead is equal to the __________.

True-False

T F 1. Similar or dissimilar materials can be joined with threaded fasteners.

T F 2. The Whitworth Thread had a standard thread angle of approximately 65°.

T F 3. The basic profile of UN and UNR threads is the same as ISO metric threads, except for the diameter and number of threads per inch.

T F 4. Screw thread series are distinguished from one another by the number of threads per inch for a series of specific diameters.

T F 5. Tolerance is the difference between the design size and the basic size of a thread.

T F 6. The tolerance for a Class 2A thread is less than the tolerance for a Class 1A thread.

T F 7. The nominal diameter of a thread may be stated in fractional or decimal dimensions in a thread note.

T F 8. The letters RH follow the thread note for right-hand threads.

T F 9. The length of a threaded fastener may be specified at the end of the thread note.

T F 10. The length of the shank of a rivet must be the same dimension as the two pieces of material to be joined.

T F 11. Riveted joints are permanent.

T F 12. A large rivet has a shank of ½″ or greater in diameter.

T F 13. A taper thread is formed on a cone or frustrum of a cone.

T F 14. A complete thread has a full format the crest and root.

T F 15. Spring lock washers are split on two sides and are helical in shape.

T F 16. Regular pipe thread is the standard for the plumbing trade.

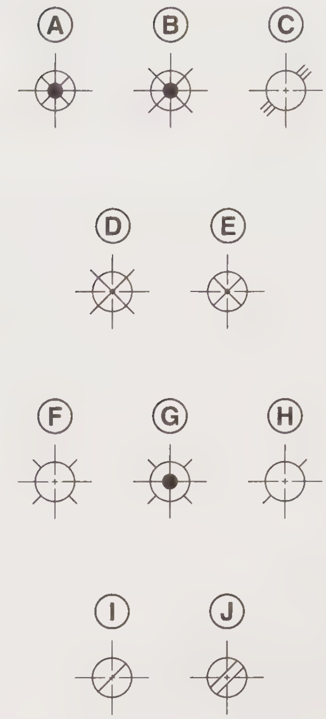
T F 17. Soft dowel pins are square on both ends.

T F 18. Spirally coiled pins have a swaged chamfer on the entry end.

T F 19. Taper keys may be easily withdrawn.

T F 20. Sealer is required with dryseal pipe threads.

Matching — Rivets



________ **1.** Shop rivet; countersunk and chipped; far side

________ **2.** Field rivet; countersunk; far side

________ **3.** Shop rivet; flattened to $\frac{3}{8}''$ for $\frac{3}{4}''$ rivets and over; near side

________ **4.** Shop rivet; countersunk; not over $\frac{1}{8}''$ high; near side

________ **5.** Field rivet; countersunk; both sides

________ **6.** Shop rivet; countersunk and chipped; both sides

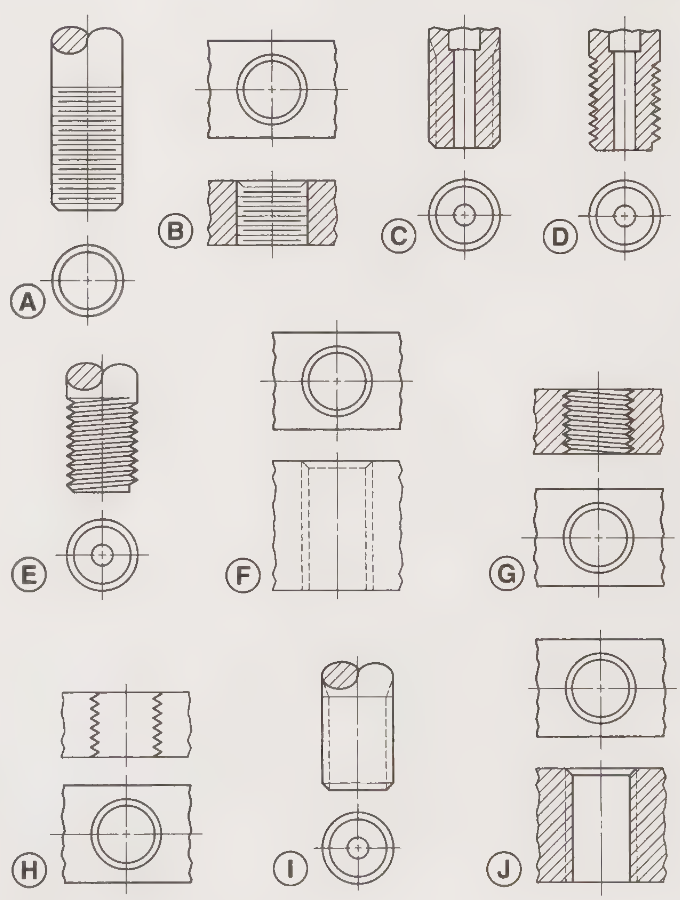
________ **7.** Shop rivet; flattened to $\frac{1}{4}''$ for $\frac{1}{2}''$ and $\frac{5}{8}''$ rivets; far side

________ **8.** Shop rivet; countersunk and chipped; near side

________ **9.** Shop rivet; countersunk; not over $\frac{1}{8}''$ high; far side

________ **10.** Field rivet; countersunk; near side

Matching — Thread Representation



________ **1.** Simplified; external; section

________ **2.** Schematic; external

________ **3.** Schematic; internal; section

________ **4.** Detailed; external

________ **5.** Simplified; internal; section

________ **6.** Simplified; internal

________ **7.** Detailed; external; section

________ **8.** Detailed; internal; section

________ **9.** Detailed; internal

________ **10.** Simplified; external

Matching — Threaded Fasteners

_______ 1. Hex cap screw

_______ 2. Cap (acorn) nut

_______ 3. Hex castle nut

_______ 4. Square set screw

_______ 5. Square nut

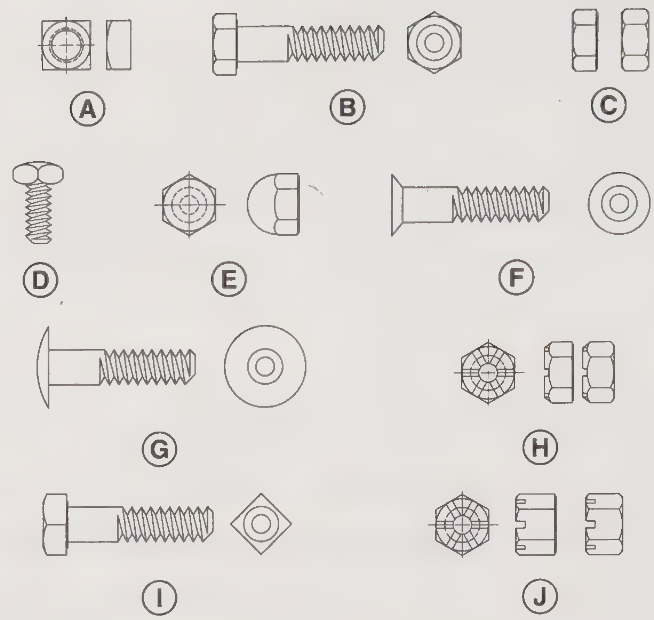
_______ 6. Round head bolt

_______ 7. Hex jam nut

_______ 8. Hex slotted nut

_______ 9. Square head bolt

_______ 10. Countersunk bolt



Matching — Screw Thread

_______ 1. Thread angle

_______ 2. Internal thread

_______ 3. Root (nut)

_______ 4. Root (screw)

_______ 5. Crest (nut)

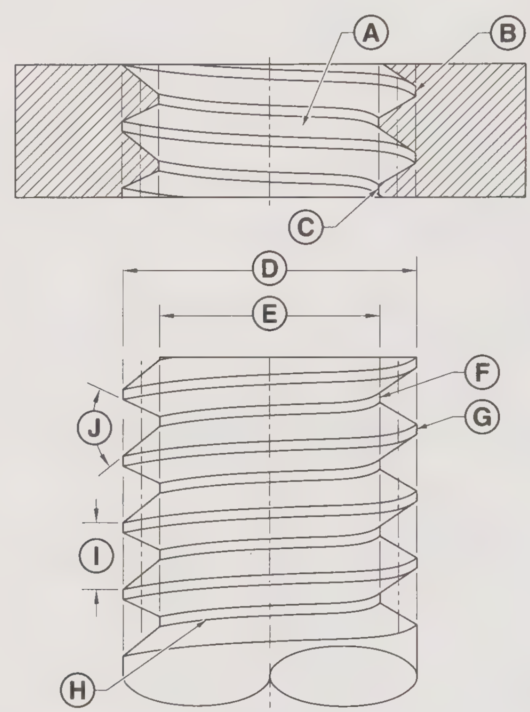
_______ 6. Crest (screw)

_______ 7. Pitch

_______ 8. Major diameter

_______ 9. Minor diameter

_______ 10. External thread



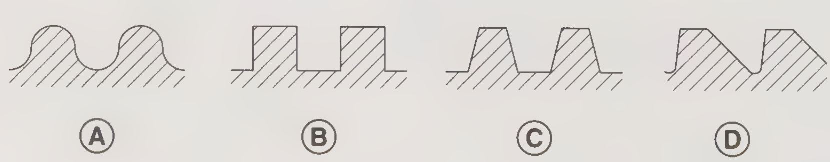
Matching — Thread Forms

_______ 1. Square

_______ 2. Buttress

_______ 3. Knuckle

_______ 4. Acme



◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Punch *(See page 125.)*

______ **1.** A No. _________ drill is used to drill the two holes.

______ **2.** Decimal tolerances for the Punch are _________″.

______ **3.** The overall diameter of the part is _________″.

______ **4.** Fractional tolerances for the Punch are _________″.

______ **5.** Two holes are drilled and tapped for _________ head cap screws.

T F **6.** Two holes are tapped for 10-32 threads.

______ **7.** The center-to-center dimension for the two holes is _________″.

______ **8.** The maximum decimal center-to-center dimension for the two holes is _________″.

______ **9.** The minimum overall decimal height of the Punch is _________″.

T F **10.** The minimum fractional radius is $3/32$″.

T F **11.** The Punch drawing was drawn by TM.

T F **12.** The overall depth of the Punch is .946″.

T F **13.** The Punch shaft is represented by hidden lines in the side view.

T F **14.** The front view and the side view are identical.

T F **15.** Through holes are drilled into the punch.

______ **16.** The print was originally drawn to the scale of _________″ = 1′-0″.

______ **17.** The manufacturer of the Punch is located in _________, IL.

______ **18.** The Punch shaft has a width of _________″.

______ **19.** The .250″ dimension in the front view is a(n) _________ dimension.

______ **20.** Approval of the print was completed on _________.

Machine Screw *(See page 125.)*

__________ 1. A(n) _________ provides the self-locking feature to the Machine Screw.

__________ 2. The maximum angle of the head is _________.

__________ 3. The overall length of the Machine Screw is _________″.

__________ 4. The Machine Screw has a cross recess type _________ drive.

T F 5. All sharp edges are to be deburred.

T F 6. The drawing may be scaled.

__________ 7. The material for the Machine Screw is _________ Series Stainless Steel.

__________ 8. The Machine Screw conforms to ANSI _________.

__________ 9. The depth of the head is _________″.

__________ 10. The Class of Thread specified is _________.

__________ 11. The nominal diameter of the Machine Screw is _________″.

__________ 12. There are _________ threads per inch on the Machine Screw.

__________ 13. The thread form on the Machine Screw is _________.

T F 14. The nylon patch may be placed on the second thread of the Machine Screw.

T F 15. The print was checked on 12-19-94.

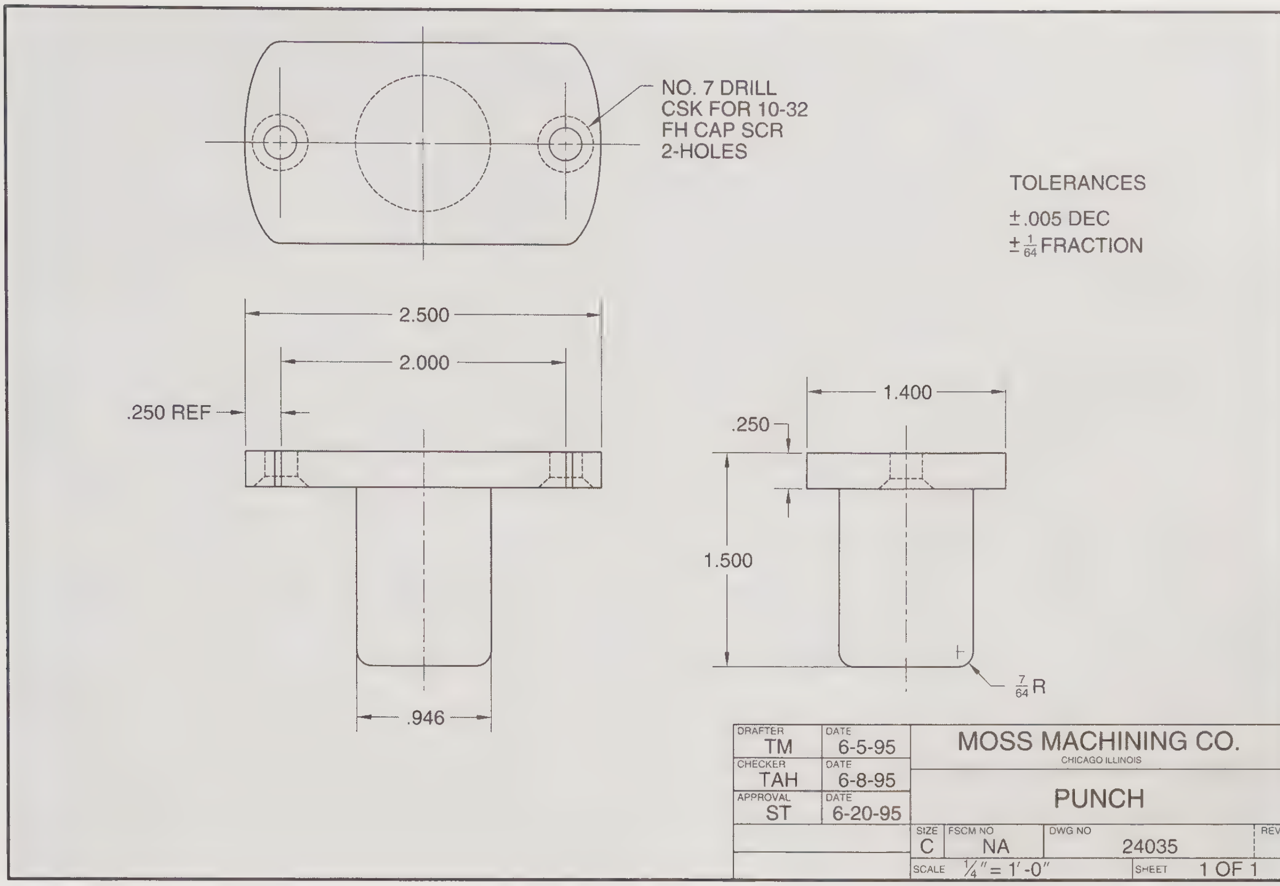
T F 16. The Machine Screw is drawn twice its actual size.

T F 17. ANSI Y14.5 applies to the drawing methods used.

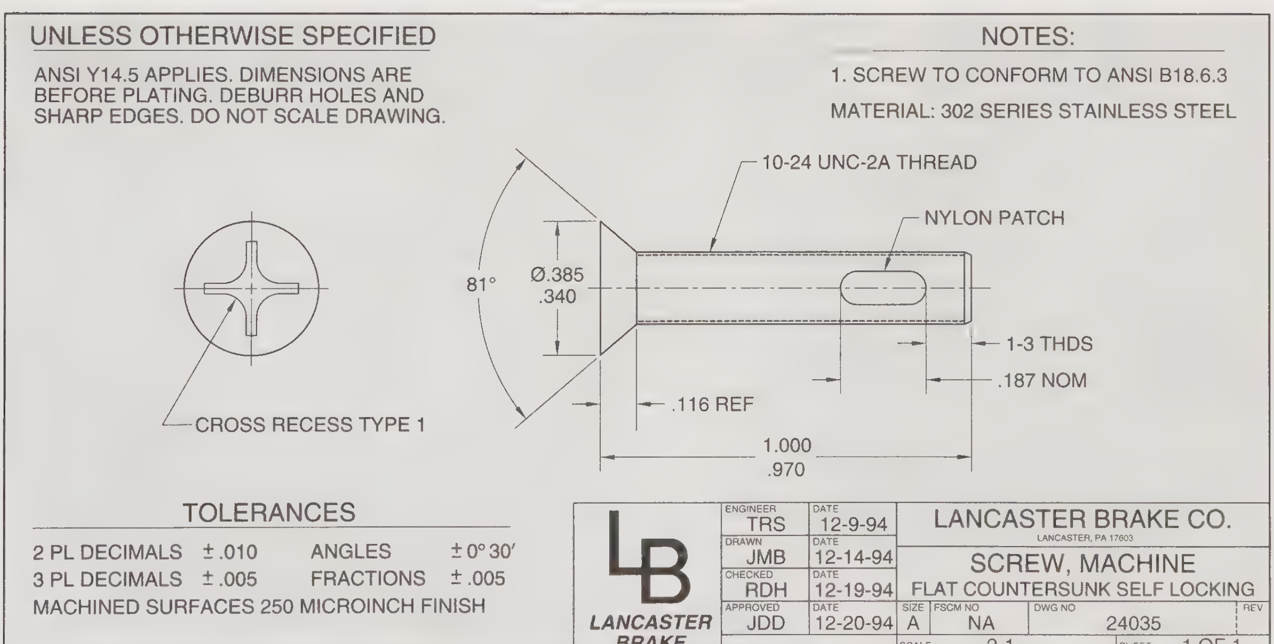
T F 18. The Machine Screw is to be plated.

__________ 19. The overall length of the nylon patch is _________″.

__________ 20. The sheet size is _________.



PUNCH



MACHINE SCREW

Plunger

________ **1.** Both ends of the Plunger are chamfered at ________°.

________ **2.** The diameter of the external thread is ________″.

________ **3.** The internal thread has ________ threads per inch.

________ **4.** The hole for the internal thread is ________″ deep.

________ **5.** The slot must be square to the flat within ________°.

________ **6.** The U-cut is made to the ________ of the external thread.

T F **7.** The external thread has two threads per inch.

T F **8.** The minimum width for the U-cut is 7/64″.

________ **9.** The overall length of the Plunger is ________″.

________ **10.** The thread form for the external thread is ________.

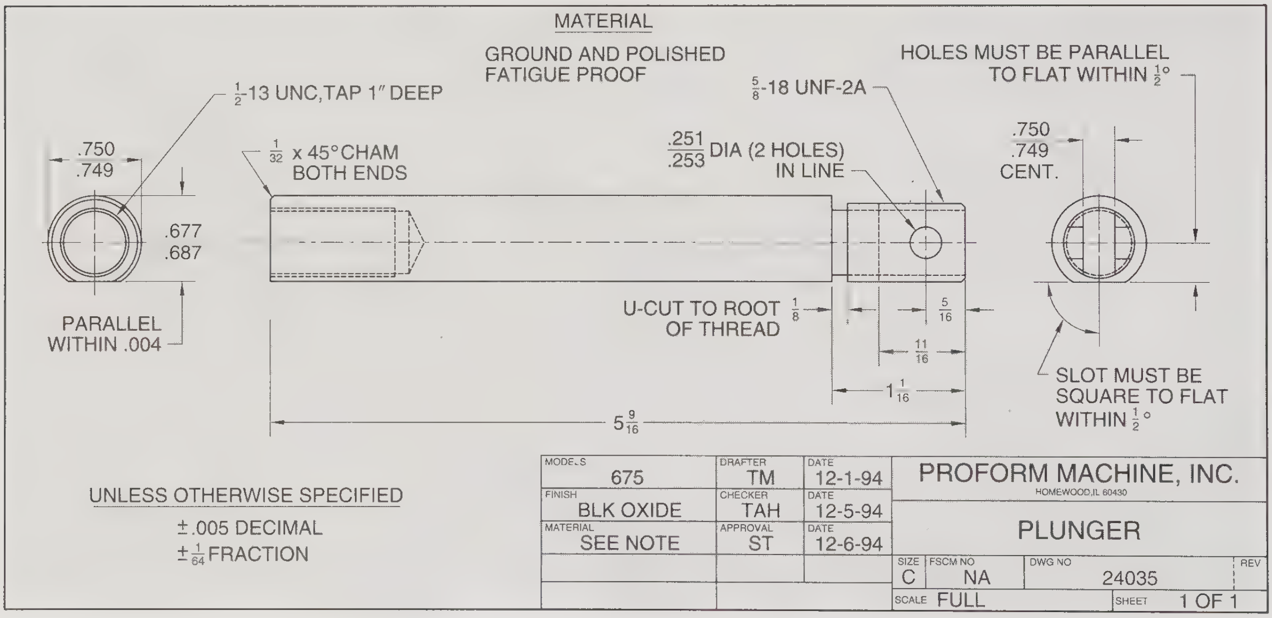
T F **11.** The Plunger is drawn full-scale.

T F **12.** Decimal tolerances are ±.005″.

________ **13.** The center of the two holes is ________″ from the right end of the Plunger.

________ **14.** The two holes are drilled to a maximum diameter of ________″.

________ **15.** The slot is ________″ deep.



PLUNGER

chapter 6

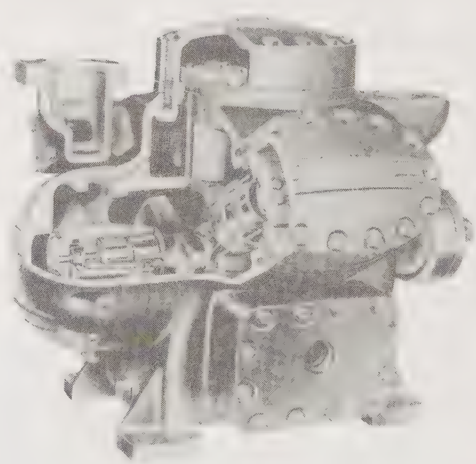
SECTIONAL VIEWS

Sectional views show the internal shapes of objects. The types of sectional views include full section, half section, offset section, broken-out section, revolved section, removed section, auxiliary section, and thin section.

SECTIONAL VIEWS

For objects which are comparatively simple in design, the problem of showing complete construction details can be achieved by orthographic representation. Many objects, however, have internal shapes which are so complicated that it is virtually impossible to show their true shape without using numerous hidden lines. See Figure 6-1. A sectional view reveals the actual internal shape of an object and retains the significant outline of the external contour.

A *sectional view* is the view of a cross-section of an object. It is commonly obtained by passing an imaginary cutting plane through the object. The cutting plane is assumed to pass through at some



Carrier Corporation

Figure 6-1. Sectional views show internal shapes of objects.

selected portion of the object and the cut part is removed. See Figure 6-2. The types of sectional views include full section, half section, offset section, broken-out section, revolved section, removed section, auxiliary section, and thin section.

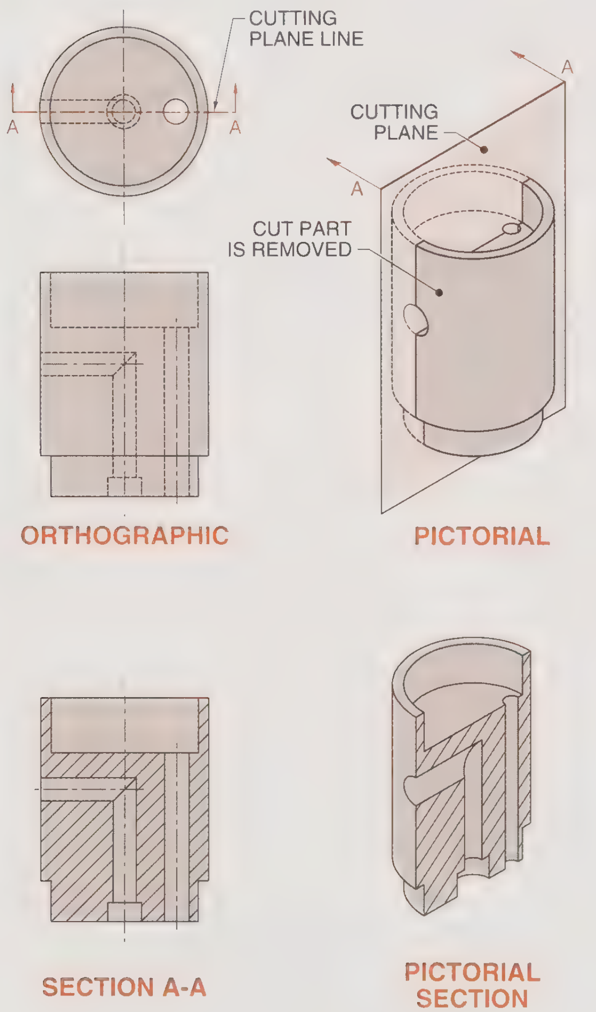


Figure 6-2. A sectional view is obtained by passing a cutting plane through the object.

Cutting Plane Line

The cutting plane is shown on the orthographic view by means of a cutting plane line. The cutting plane line is thick with ¾″–1½″ long dashes and ⅛″ short dashes. All spaces between dashes are 1⁄16″. The arrowheads should point in the direction of sight in which the object is viewed when the sectional view is made. See Figure 6-3.

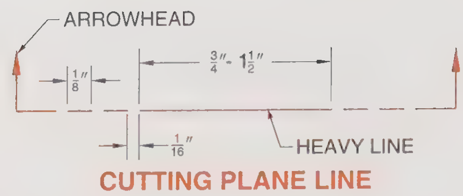


Figure 6-3. The cutting plane line is thick with long and short dashes.

Uppercase letters such as A-A, B-B, C-C, etc., are used to identify the section. The letters should read horizontally, should not be underlined, and should be located adjacent to the arrowheads. A notation is also placed under the view as SECTION A-A. See Figure 6-4.

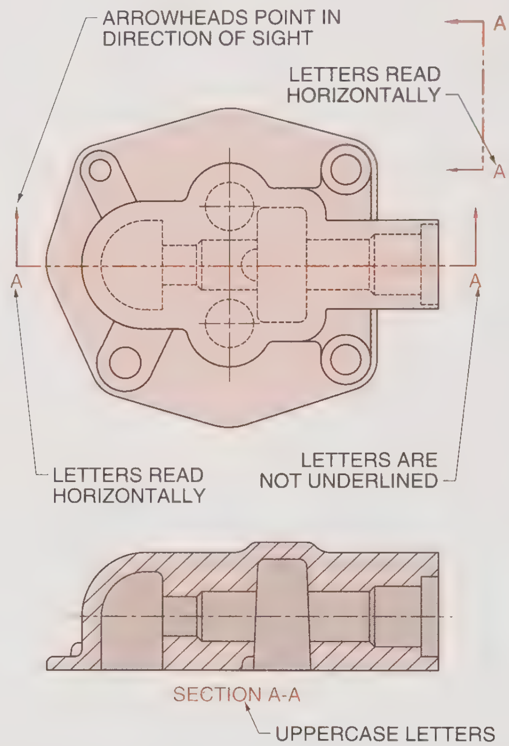


Figure 6-4. Uppercase letters are used to identify the section.

On objects with one major center line in which the cutting plane is assumed to pass through the axis of symmetry, the cutting plane line may be omitted since its position is already clear that the section is taken along that center line. See Figure 6-5.

The cutting plane line may be offset if construction can be shown more clearly or thoroughly. The cutting plane line preferably should be shown through an exterior and not through a sectional view.

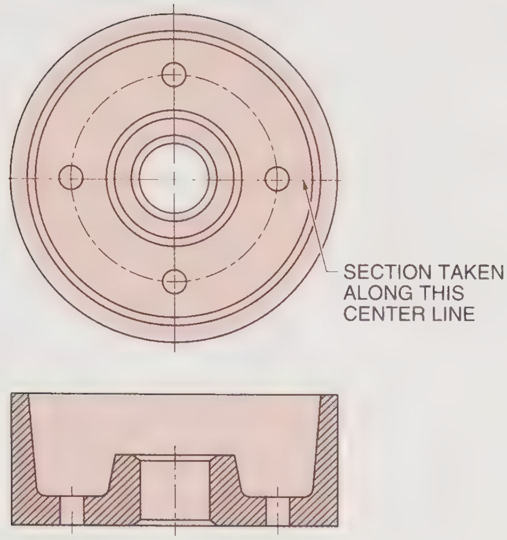


Figure 6-5. The cutting plane may be omitted if a section is taken along a major center line.

Full Section

A *full section* is a sectional view in which the cutting plane passes entirely across the object. See Figure 6-6. The half of the object between the observer and the cutting plane is considered to be removed and the remaining half (in full section) exposed to view. Full sections are commonly used.

Half Section

A *half section* is a sectional view in which two cutting planes are passed at right angles to each other along the center lines or symmetrical axes. See Figure 6-7. Passage of the cutting planes permit the removal of one-quarter of the object and a half section of the interior is exposed to view.

A half section has the advantage of showing the interior of the object and at the same time maintaining the shape of the exterior. It is used with symmetrical objects only. A *symmetrical object* is an object in which one half is the mirror image of the other half. An *asymmetrical object* is an object in which one half is not the mirror image of the other half. Half sections are not used with asymmetrical objects.

Because it is often difficult to completely dimension the internal shape of a half section, this type of section view is not widely used in detail drawings. It is used in assembly drawings where it is necessary to show both internal and external construction on the same view.

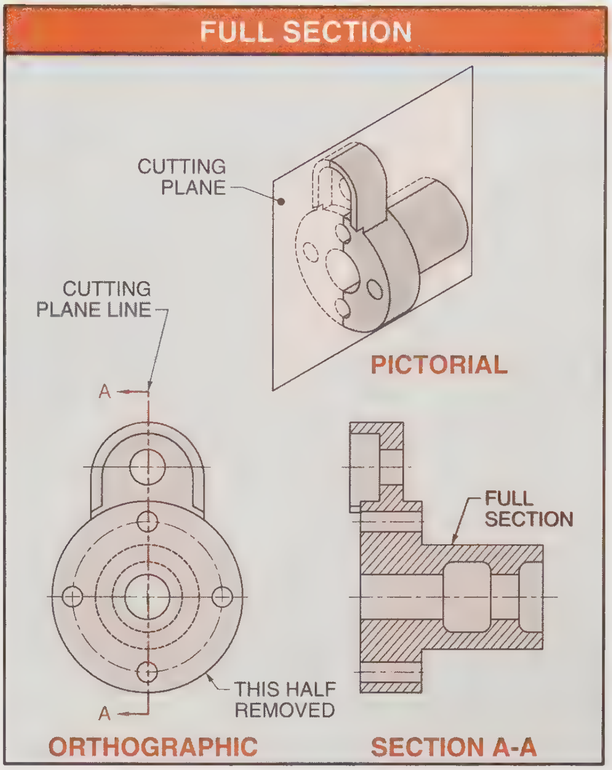


Figure 6-6. A full section is a sectional view in which the cutting plane passes entirely across the object.

Offset Section

An *offset section* is a sectional view in which the direction of the cutting plane line changes direction from along the main axis to include features which are not located in a straight line. The cutting plane is offset to pass through these features. See Figure 6-8.

By offsetting the cutting plane in several places, the shape of the openings and recess which normally would not be seen with a regular full section can be viewed. In making an offset section the offsets are not included in the sectional view but only in the view showing the cutting plane line.

Broken-out Section

A *broken-out section* is a sectional view in which a small portion designated by a freehand break line is removed. By removing only a small portion it is often possible to preserve some detail of the object that otherwise would be eliminated in a full or half section. No cutting plane line is necessary to show a broken-out section. See Figure 6-9.

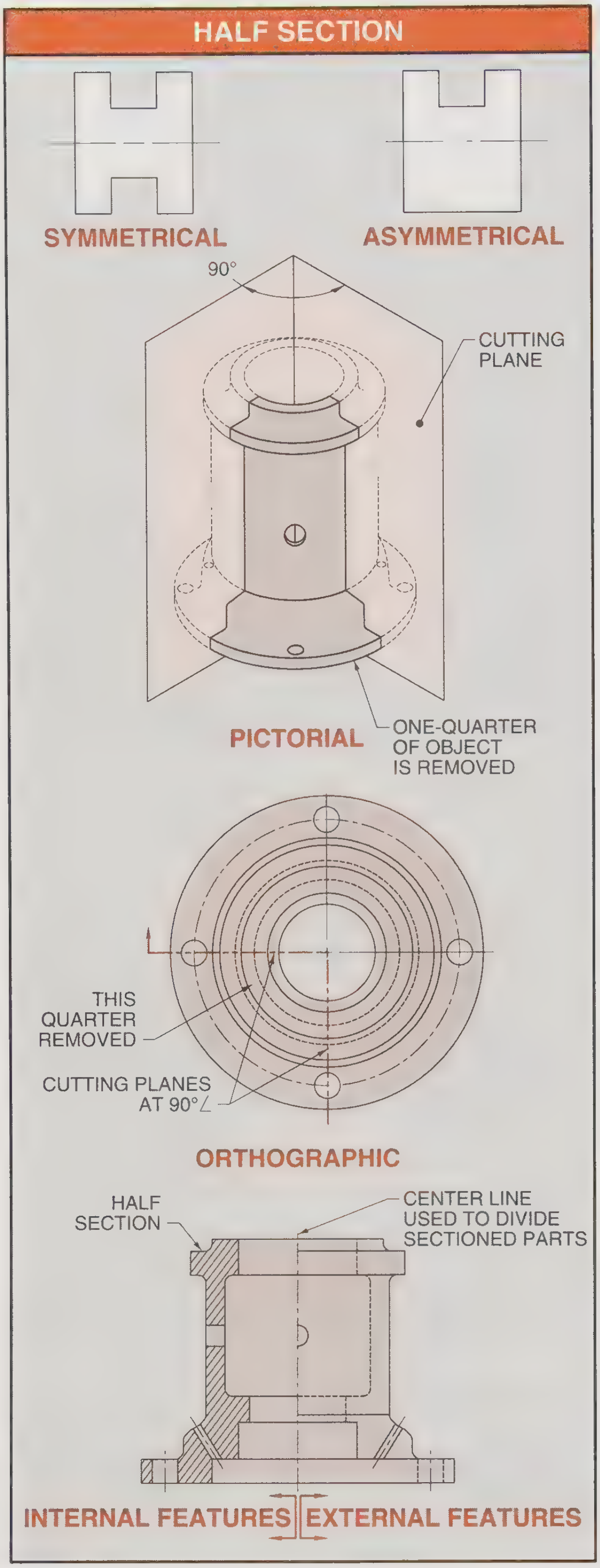


Figure 6-7. A half section is a sectional view in which two cutting planes are passed at right angles to each other along the center line.

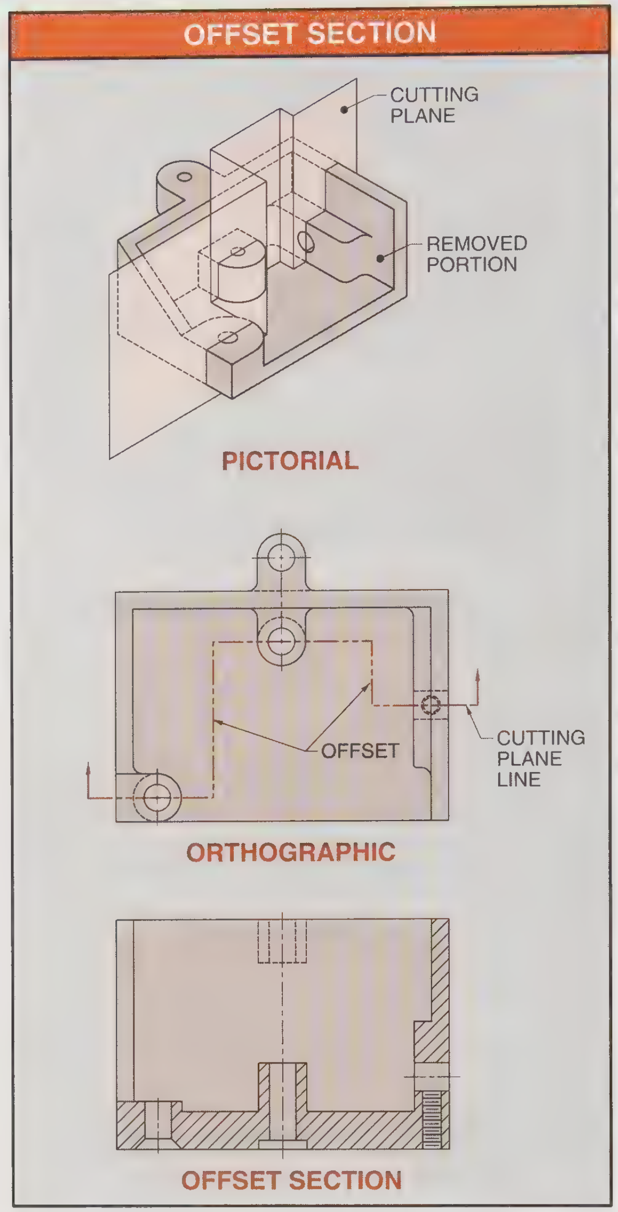


Figure 6-8. An offset section is a sectional view in which the cutting plane line is offset to pass through features not located in a straight line.

Revolved Section

Revolved sections are sectional views that show the actual crossectional shape of elongated parts. Typical parts commonly shown with revolved sections include bars, spokes, arms, ribs, etc.

The cutting plane is passed perpendicular to the axis of the piece and then revolved in place through 90° into the plane of the sheet. The visible lines on each side of the adjacent view may be removed and broken lines used to leave the revolved section clear.

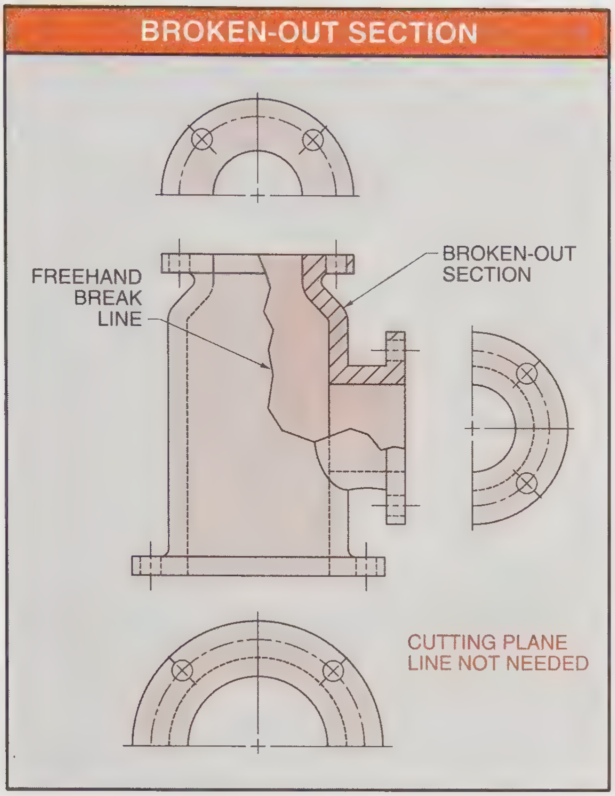


Figure 6-9. A broken-out section is a sectional view in which a small portion designated by a freehand break line is removed.

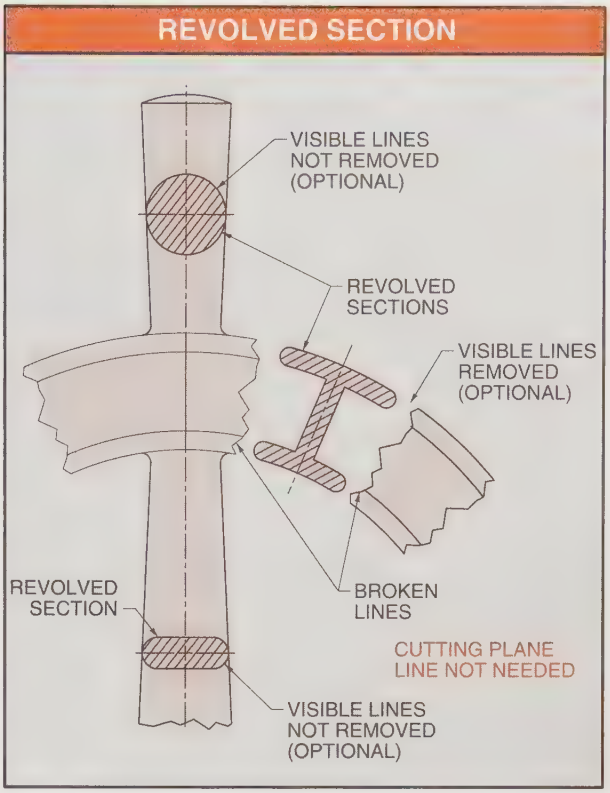


Figure 6-10. A revolved section is a sectional view that shows the cross sectional shape of elongated parts.

The true shape of the exposed revolved section should always be retained regardless of the direction of the contour lines of the object. No cutting plane line is necessary to show a revolved section. See Figure 6-10.

Removed Section

A *removed section* is a sectional view that is detached from the projected view and located elsewhere on the sheet. By removing the section, the regular view can be left intact and the removed section drawn to a larger scale to facilitate more complete dimensioning. See Figure 6-11.

A removed section should be labeled in uppercase lettering, as SECTION B-B, to identify it with the cutting plane line which is labeled with corresponding letters at the ends.

A removed section should be placed in a convenient location; if possible, on the same sheet with the regular view. On multiple-sheet drawings where it is not practical to place a removed section on the same sheet with the regular views, identification and zoning references should be indicated on related sheets. Below the section title, the sheet number where the cutting plane line is located should be given as:

SECTION B-B
ON SHEET 4, ZONE A3

A similar note should be placed on the drawing where the cutting plane is shown, with a leader pointing to the cutting plane, referring to the sheet where the section is located.

If two or more sections appear on the same sheet, they should, if possible, be arranged in alphabetical order from left to right. Section letters should be used in alphabetical order, but use should not be made of the letters I, O, and Q, to avoid confusing the I with the number 1, or the O with the Q, or zero. If more than 23 sections are used, the additional sections should be indicated by double letters in alphabetical order, AA-AA, BB-BB, etc.

A removed section may be drawn to a larger scale if necessary, in which case the scale should be shown under the section title. Removed sections may be placed on center lines extended from the section cuts.

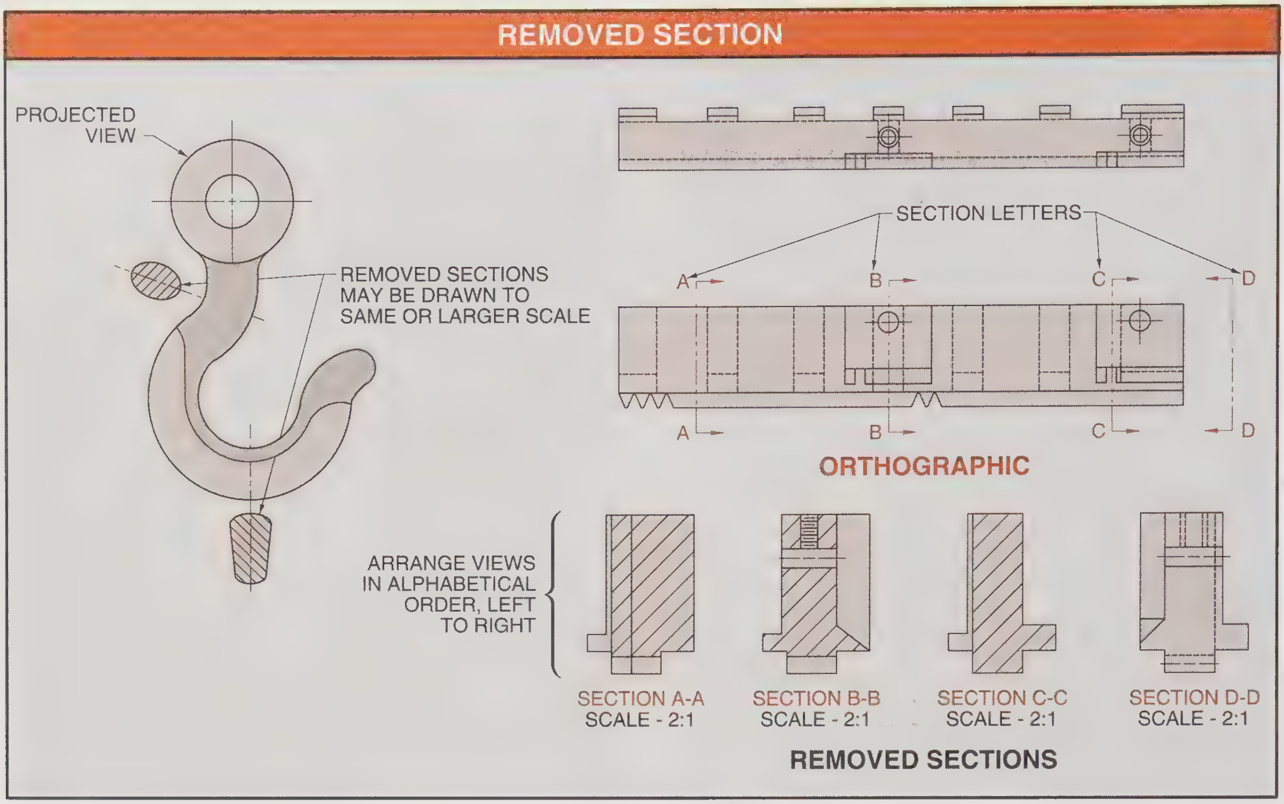


Figure 6-11. A removed section is a sectional view that is detached from the projected view.

Auxiliary Sections

An *auxiliary section* is a sectional view that is not one of the principal planes. An auxiliary section may be full, half, broken-out, removed, or revolved. The section should be shown in its normal auxiliary position and clearly identified with a cutting plane and appropriate letters. See Figure 6-12.

Thin Section

A *thin section* is a sectional view that is too thin to be shown by the ordinary cross-sectioning convention material commonly drawn as thin sections include sheet metal, gaskets, packing, etc. See Figure 6-13.

Cross sections of thin material are drawn in solid black. If two or more pieces are adjacent to each other, a white space is left to separate the section.

Some industries specify that where two or more adjacent thin sections are used, they shall be shown solid, but an additional exploded view of that portion shall be included to properly define the arrangement of parts.

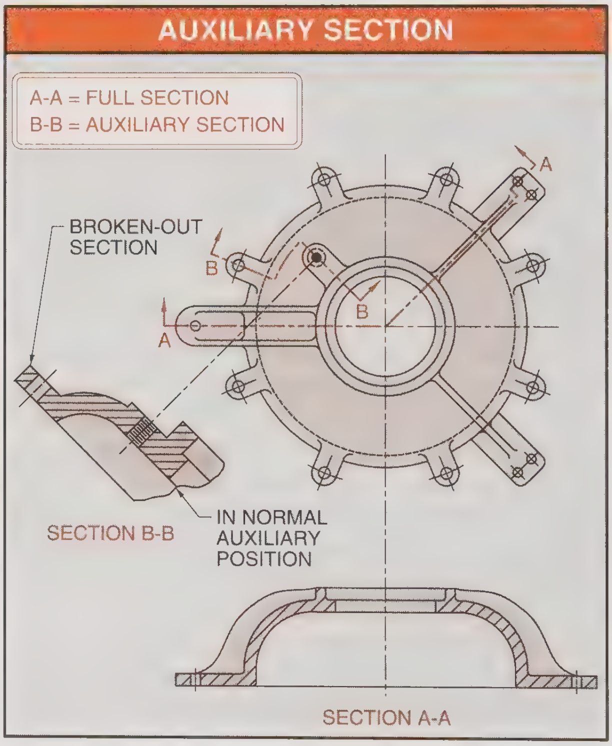


Figure 6-12. An auxiliary section is a sectional view that is not one of the principal planes.

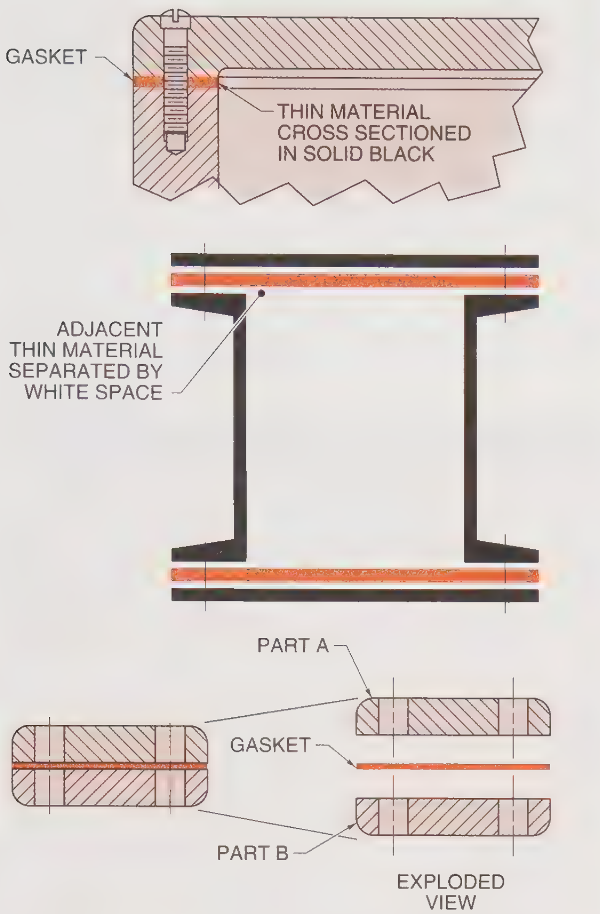


Figure 6-13. A thin section is a sectional view that is too thin to be shown by the ordinary cross-sectioning convention.

Section Lining

Section lining is a series of thin, even-spaced, diagonal lines that show the surfaces through which the cutting plane has passed. To clearly define the surfaces of a section, thin lines are drawn across the cut area at a 45° angle with the horizontal. See Figure 6-14.

If the section consists of two adjacent parts, such as in an assembly drawing, the section lines should run in opposite directions in order to provide contrast. When three parts form the section, the third part adjacent to the first two should have lines sloping at 30° or 60° with the main outline of the view. For additional adjacent parts, the lines may be drawn at any suitable angle just so each part stands out separately and clearly.

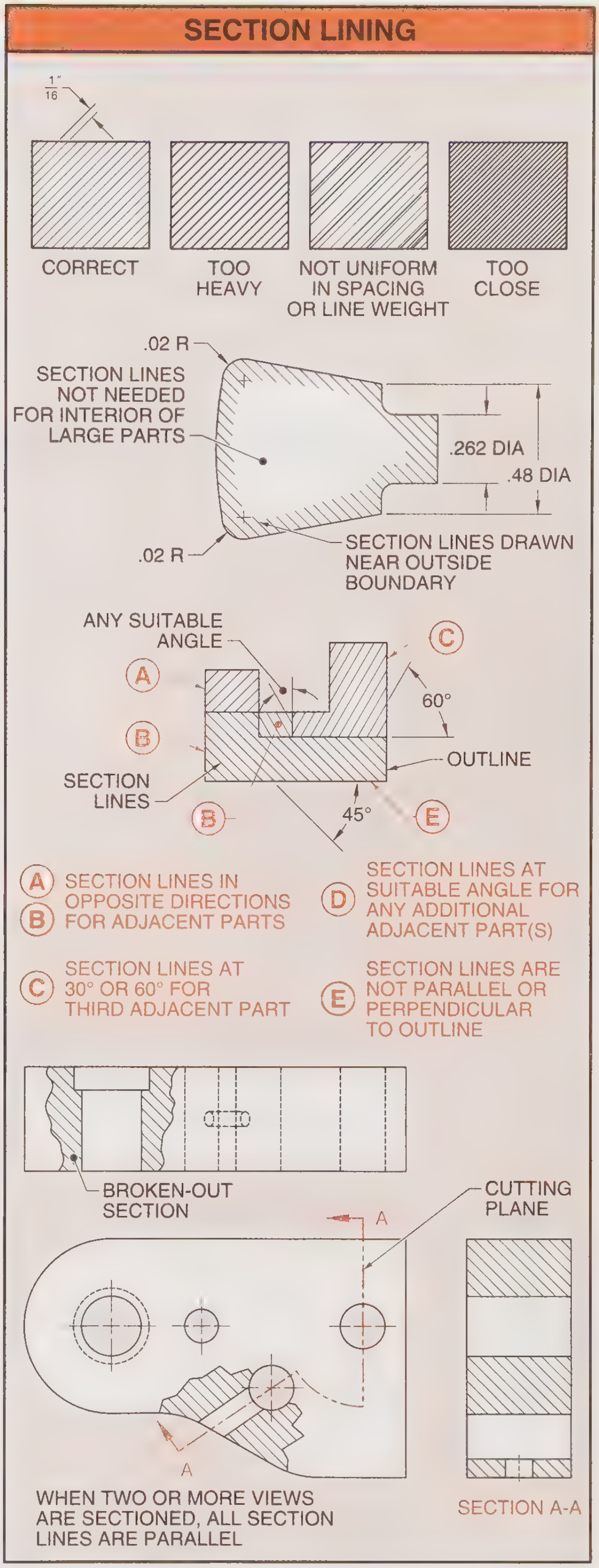


Figure 6-14. Section lining is a series of thin, even-spaced, diagonal lines that show the surfaces through which the cutting plane has passed.

All lines should be uniformly spaced from approximately $\frac{1}{16}''$ or more apart. The actual spacing depends on the size of the drawing.

If the shape or portion of a sectional area is such that the section lines would be parallel or nearly perpendicular to the dominant visible lines of the section, the section lines must be drawn to some other angle.

In sectioning very large areas, it is permissible to use section lines only near the adjacent boundary of the sectioned area with the interior portion left clear.

All the sectioned areas of a single part should be lined in the same direction and with the same angle of slope. If an object has three views and two or more views are sectioned, the section lines must all be drawn parallel.

Section Lining Symbols

Section lining symbols are standard conventions that show materials. See Figure 6-15. ANSI Y14.2 illustrates the various symbols which may

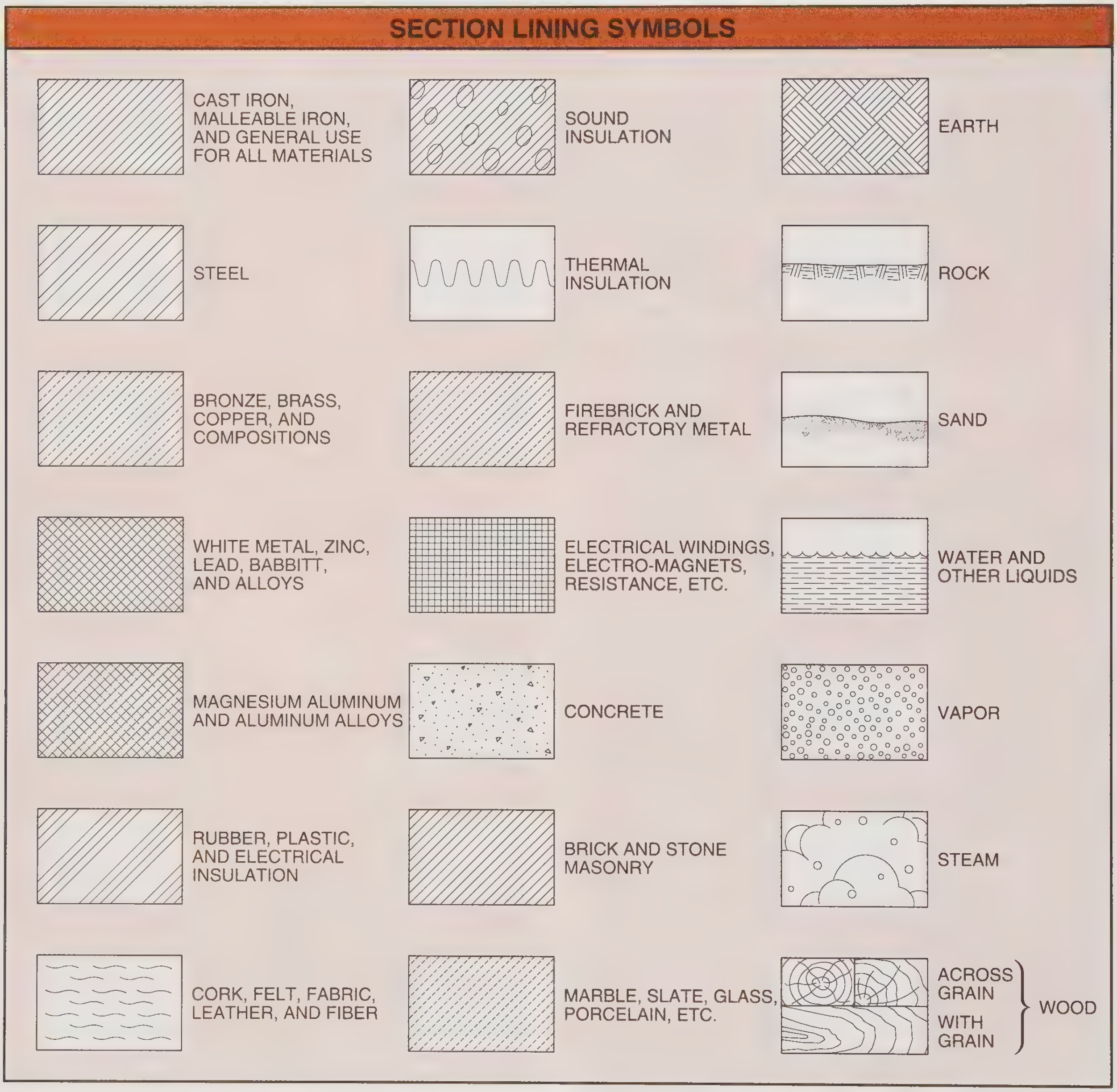


Figure 6-15. Section lining symbols are standard conventions that show materials.

be used for sectioning. These symbols are used on assembly drawings where it is only desirable to distinguish between the different classes of materials without specifying their exact composition. On detail drawings, the all-purpose cast iron symbol is recommended, except for parts made of wood, with the exact specification of the material given in a note near the view or in the title strip or parts list.

Hidden Lines

As a rule, all hidden lines should be omitted from a sectional view. The only exception is when hidden lines are absolutely indispensable for clarification or for dimensioning. In half sections, hidden lines should be used only on the unsectioned side, providing they are necessary for dimensioning or clarity. See Figure 6-16.

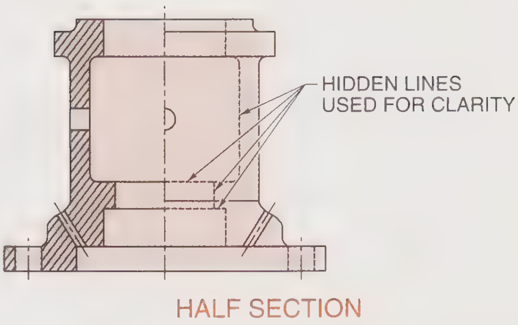


Figure 6-16. Hidden lines are placed on a section view only for clarity or dimensioning.

Sections Through Webs or Ribs

When the cutting plane passes flatwise through a web, rib, gear tooth, or other similar flat elements, the element should not be sectioned to avoid presenting a false impression of thickness or solidity. See Figure 6-17A.

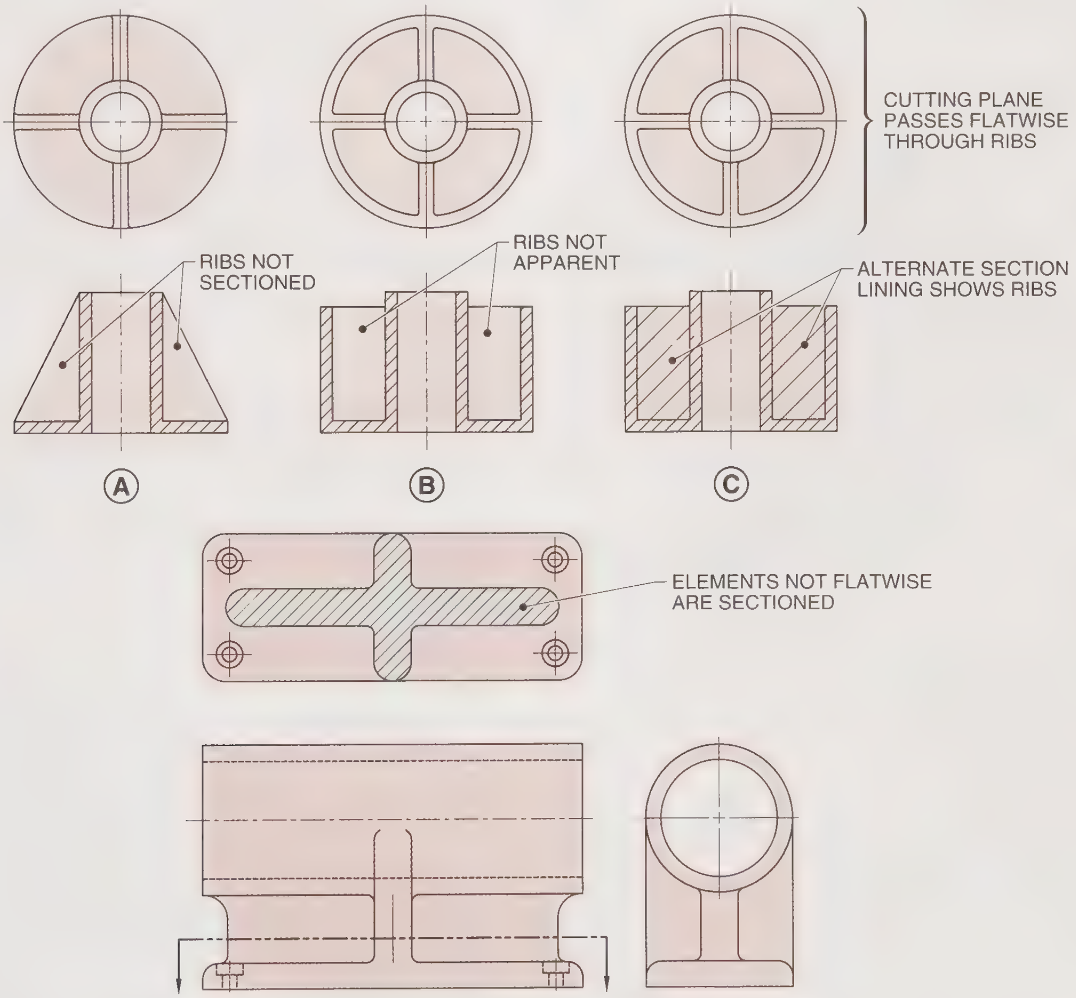


Figure 6-17. Webs, ribs, gear teeth, etc. in which the cutting plane passes flatwise are not sectioned.

Alternate section lining may be used in cases where the actual presence of a flat element is not sufficiently clear without section lining, or where clear description of the feature may be improved. For example, in Figure 6-17B, the presence of the ribs is not immediately clear in the sectional view; while in Figure 6-17C, the alternate section lining is used to show the ribs. Alternate section line spacing is twice as wide as in normal sections.

If the cutting plane cuts across elements that are not flatwise, the elements should be section-lined in the usual manner.

Sections Through Shafts, Bolts, Pins

When the cutting plane contains the center lines of such elements as shafts, bolts, nuts, rods, rivets, keys, pins, spokes, screws, ball or roller bearings, or similar shapes, no sectioning is needed. See Figure 6-18. If the cutting plane cuts across the axes of elongated parts they should be sectioned in the usual manner.

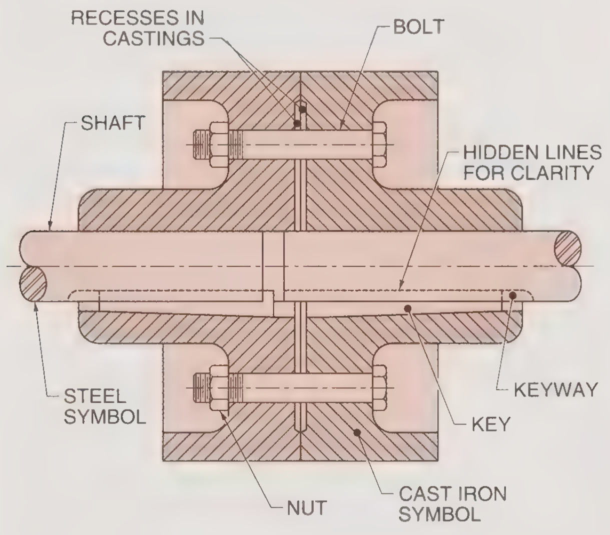


Figure 6-18. Elements such as bolts, screws, and pins should not be sectioned.

Conventional Breaks

A *conventional break* is a standard method of showing breaks in long objects. The conventional break allows both ends of the object to be shown and conserves drawing space. For example, objects such as rods, tubes, bars, etc. may be drawn using conventional breaks. See Figure 6-19.

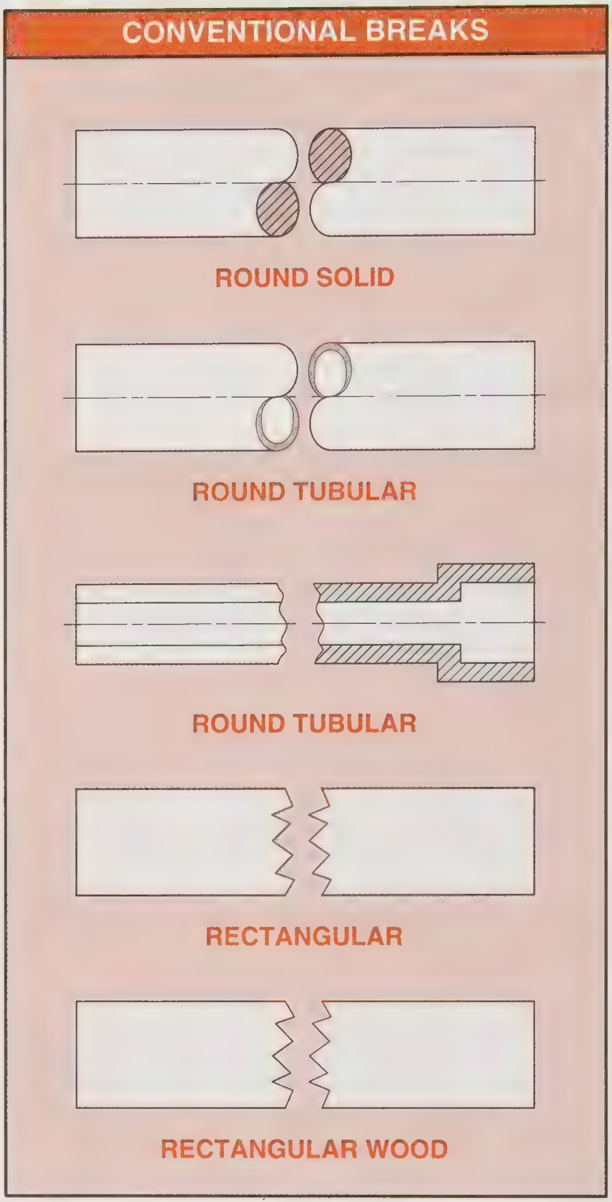


Figure 6-19. Conventional breaks may be used with long objects.

Foreshortened Projections and Related Features

If the true projection of inclined elements result in foreshortening, the elements should be rotated into the plane of the paper. *Foreshortening* is the apparent shortening of particular parts. See Figure 6-20.

In drawings of drilled flanges the holes may be rotated to be shown at their true distance from the center rather than in true projection, if clearness is promoted.

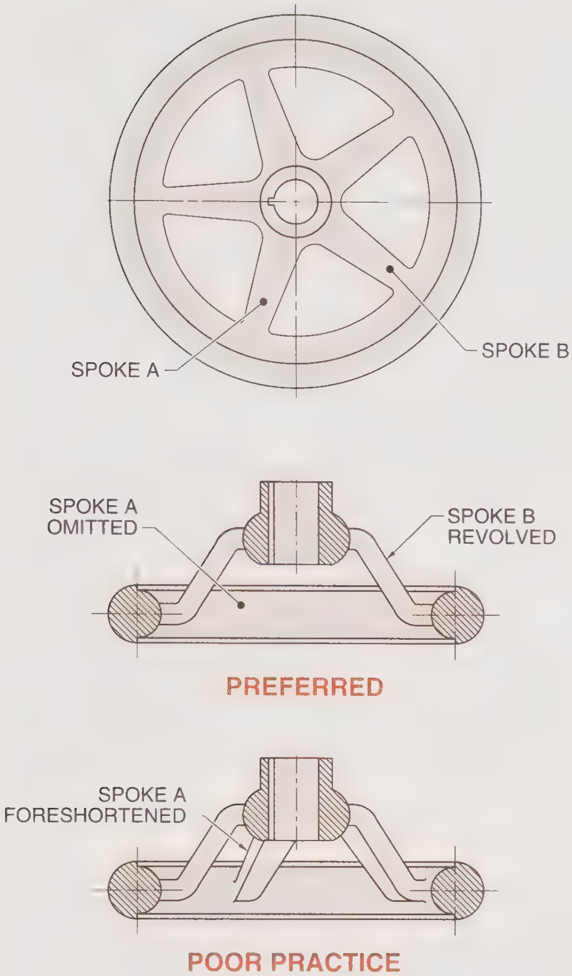


Figure 6-20. Foreshortening is the apparent shortening of particular parts.

To include features not along a straight line, the cutting plane may be bent or changed in direction to pass through these features and the sections drawn as if they were rotated into a plane. Such sections are known as aligned sections, whether features are rotated into the cutting plane or the cutting plane is bent to pass through them. See Figure 6-21.

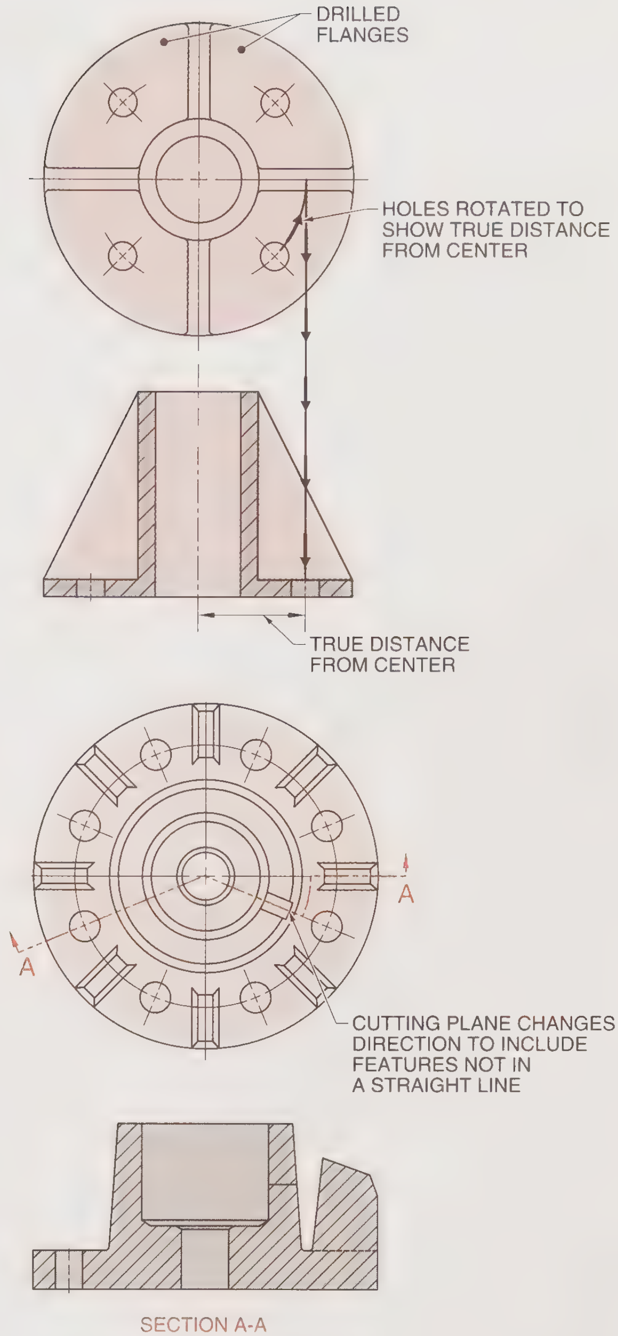
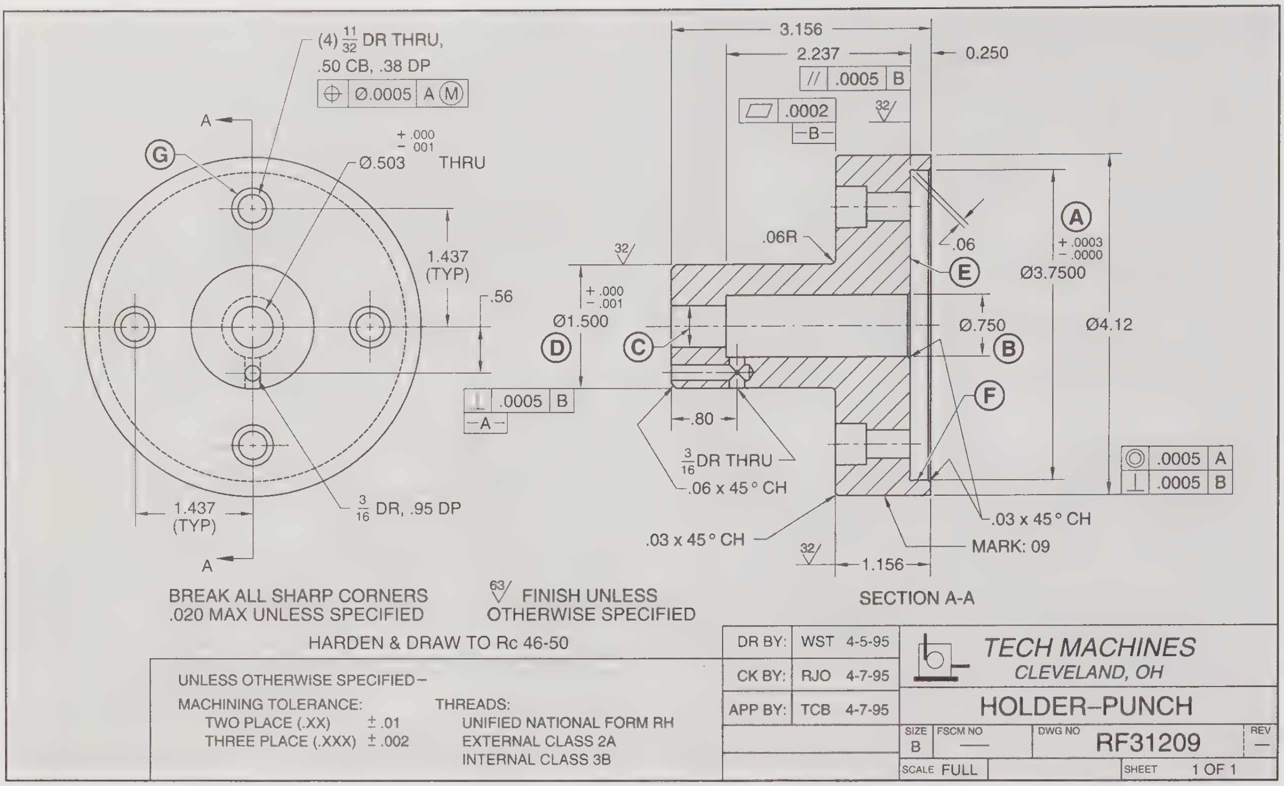
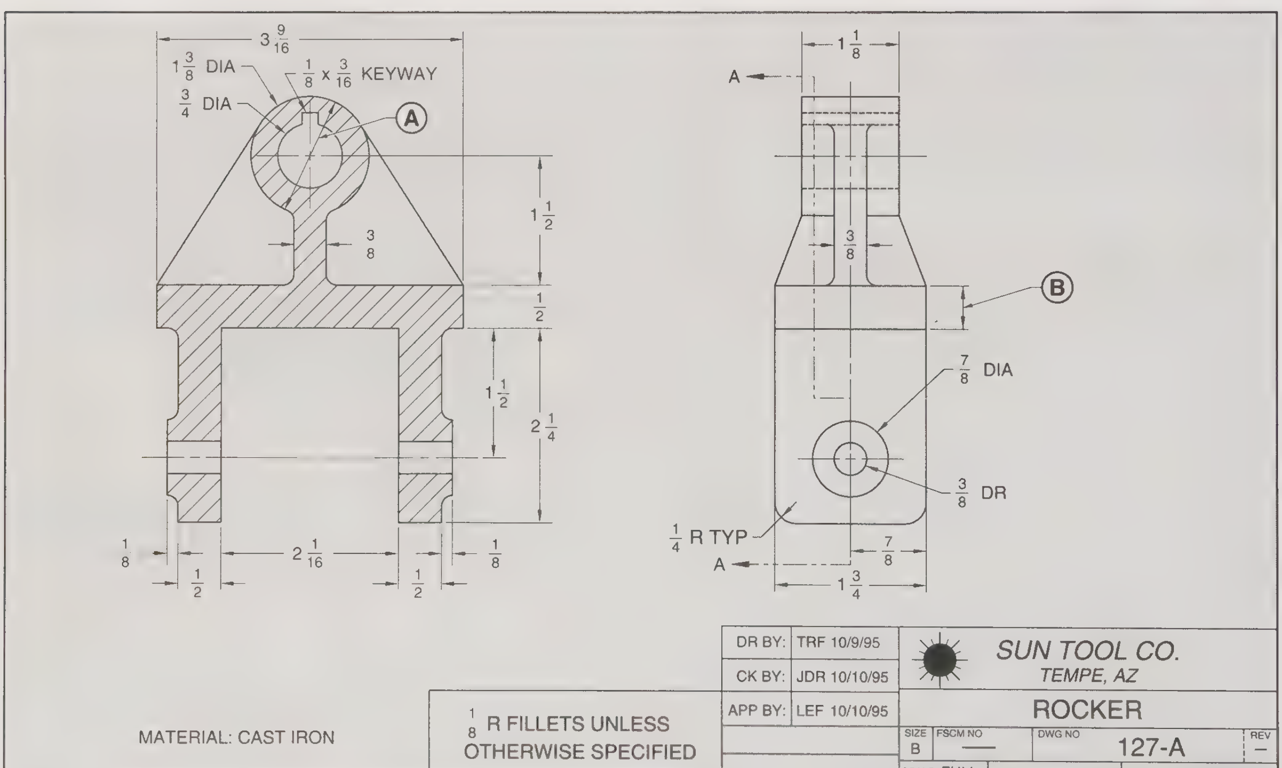


Figure 6-21. Features are rotated or cutting planes change direction to show true distances and shapes.



HOLDER–PUNCH



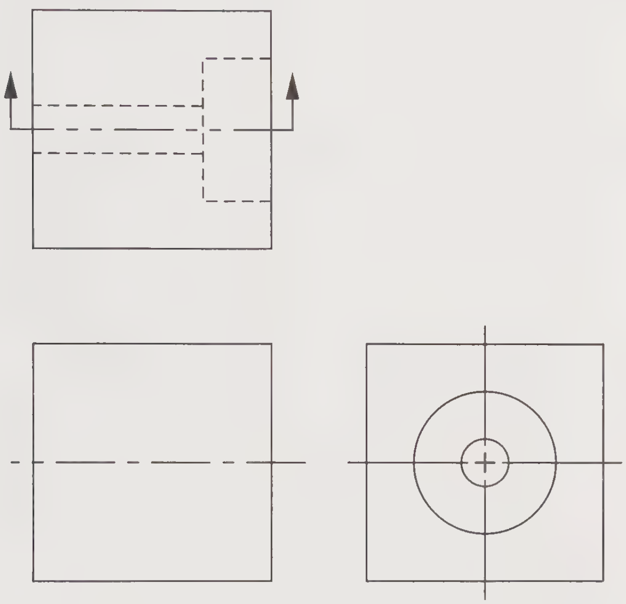
ROCKER

Name ______________________________ Date ______________

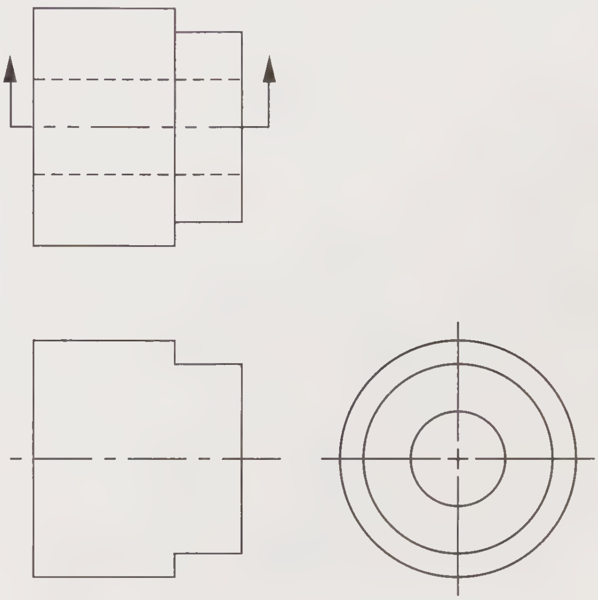
Sketching — Sectional Views

Sketch views as indicated.

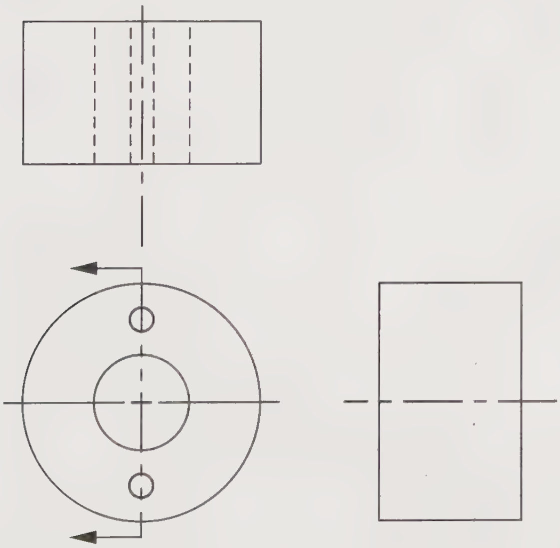
(1) FULL SECTION



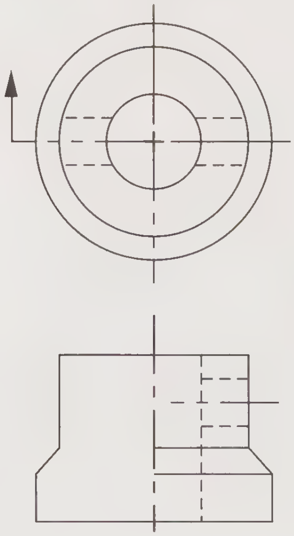
(2) FULL SECTION



(3) FULL SECTION Material: Brass

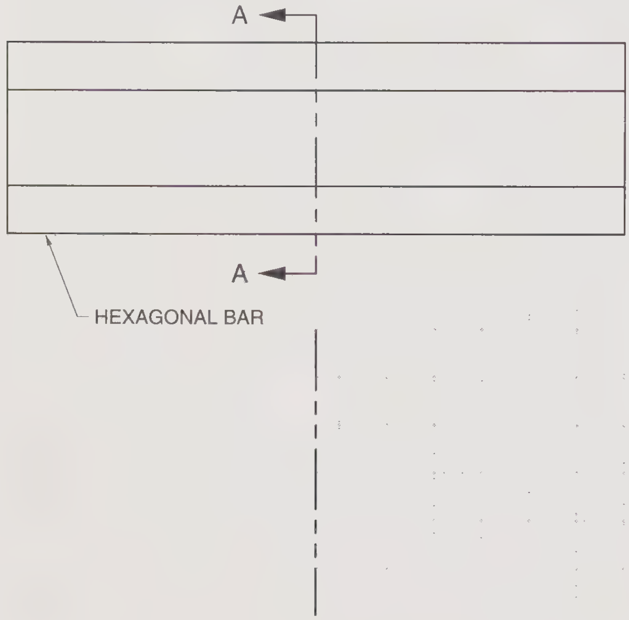


(4) HALF SECTION Material: Steel



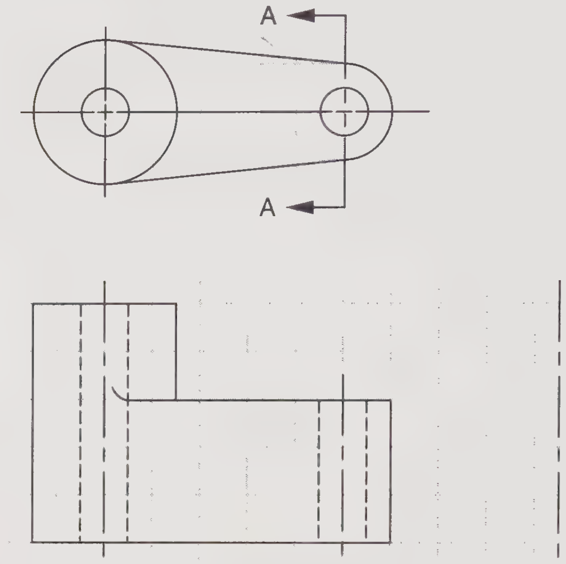
Sketching — Sectional Views (continued)

5 REVOLVED SECTION



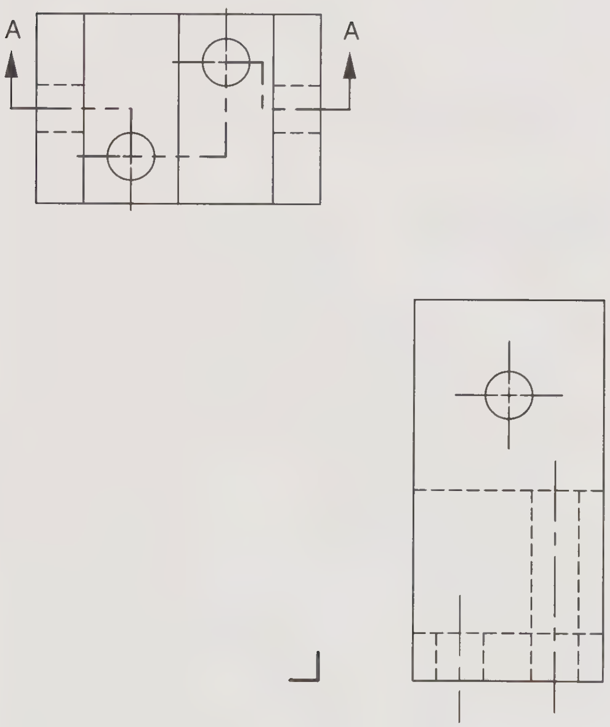
SECTION A-A

6 REMOVED SECTION



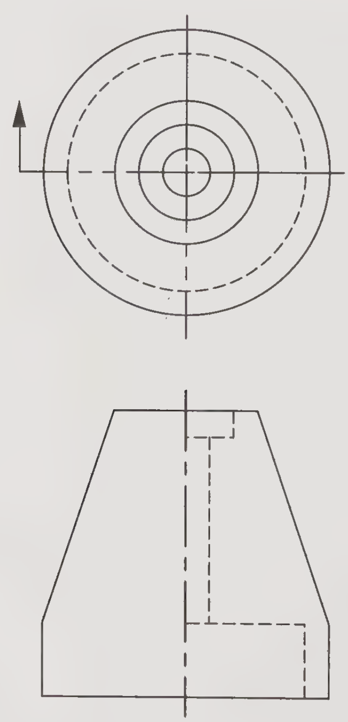
SECTION A-A

7 OFFSET SECTION



SECTION A-A

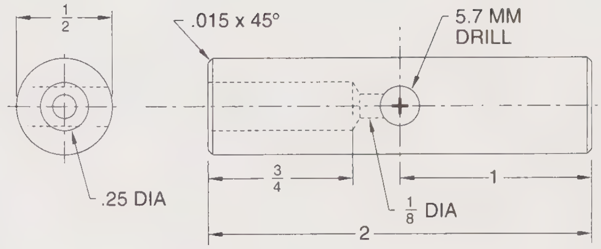
8 HALF SECTION



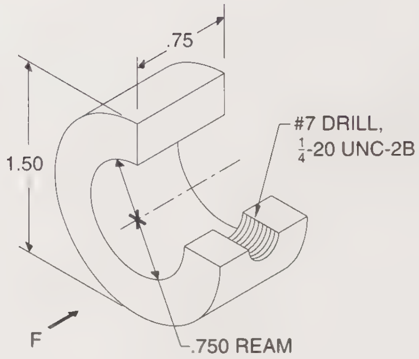
Sketching — Dimensioned Sectional Views

Sketch views as indicated.

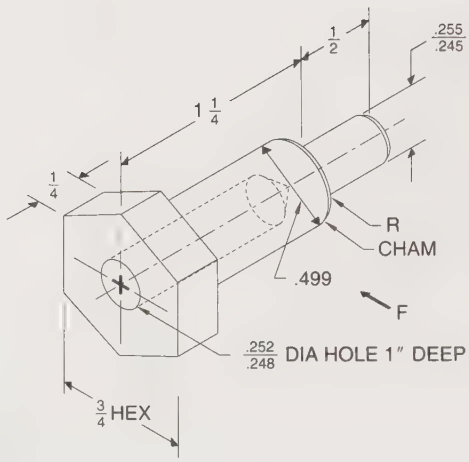
(1) PIN – Broken-out section.
Material: Steel



(2) COLLAR – Orthographic and half section.
Material: Aluminum



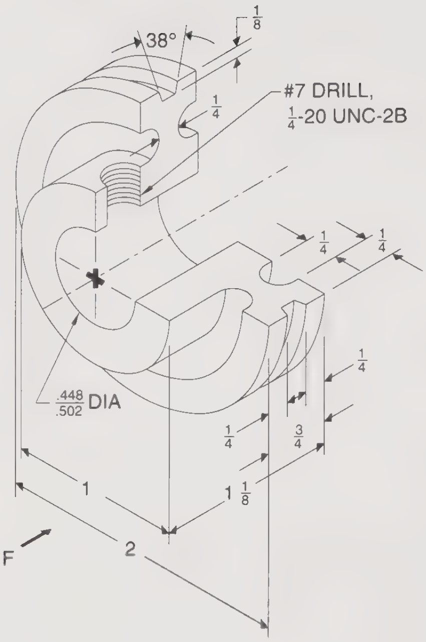
(3) SHAFT – Orthographic and full section.
Material: Aluminum



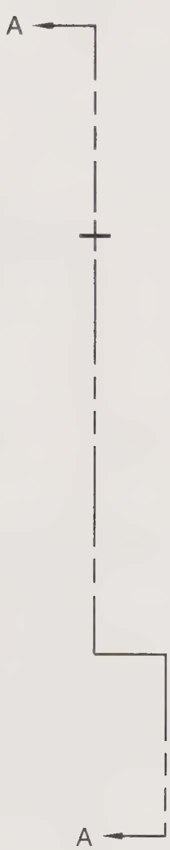
Sketching — Dimensioned Sectional Views (continued)

(4) V-BELT SHEAVE – Orthographic and half section.
Material: Cast Steel

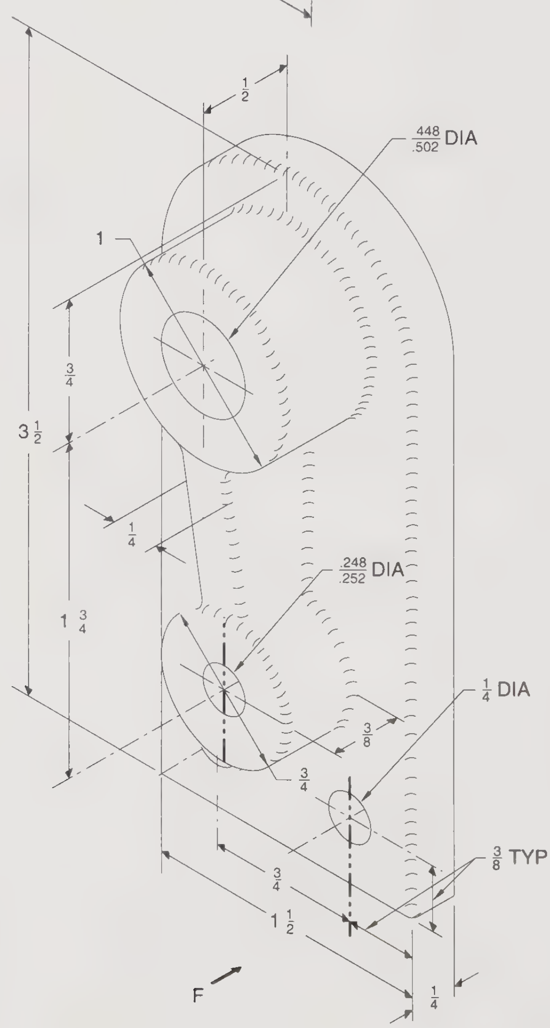
SECTION



(5) MOUNT – Orthographic and offset full section.
Material: Cast Iron



SECTION A-A



Ø6 A1

Review Questions

Name ______________________________ Date ______________

Completion

______ **1.** The cutting plane line is thick with ________″ long dashes and ⅛″ short dashes.

______ **2.** A(n) ________ section is a sectional view in which the cutting plane passes entirely across the object.

______ **3.** A(n) ________ section is a sectional view in which two cutting planes are passed at right angles to each other along the centerlines or symmetrical axes.

______ **4.** A(n) ________ object is an object in which one half is the mirror image of the other half.

______ **5.** ________ sections are sectional views that show the actual crossectional shape of elongated parts.

______ **6.** A(n) ________ section is a sectional view that is not one of the principal planes.

______ **7.** Section ________ is a series of thin, even-spaced, diagonal lines that show the surfaces through which the cutting plane has passed.

______ **8.** As a rule, all ________ lines should be omitted from a sectional view.

______ **9.** Cross sections of ________ material are drawn in solid black.

______ **10.** ________ letters are used to identify sections.

______ **11.** A(n) ________ section shows the interior of an object while maintaining the shape of the exterior.

______ **12.** The cutting plane line changes direction in a(n) ________ section.

______ **13.** A(n) ________ section is detached from the projected view and located elsewhere on the sheet.

______ **14.** Section lines are uniformly spaced approximately ________″ or more apart.

______ **15.** ANSI ________ illustrates the various symbols which may be used for sectioning.

True-False

T F **1.** A sectional view is the view of a cross-section of an object.

T F **2.** Letters identifying sections should read vertically.

T F **3.** A cutting plane line may be omitted if it is clear that the section is taken along the centerline.

T F 4. Full sections are the most commonly used sections.

T F 5. Half sections are not widely used in detail drawings.

T F 6. A cutting plane line is required to show a broken-out section.

T F 7. Two or more removed sections on the same sheet should be arranged in alphabetical order from left to right.

T F 8. The sectioned areas of a single parts should be lined in the same direction.

T F 9. In half sections, hidden lines should be used only on the sectioned side.

T F 10. Alternate section line spacing is the same width as in normal sections.

Matching — Section Lining Symbols

______ 1. Earth

______ 2. White Metal, Zinc, Lead, Babbitt, and Alloys

______ 3. Concrete

______ 4. Bronze, Brass, Copper, and Compositions

______ 5. Rubber, Plastic Electrical Insulation

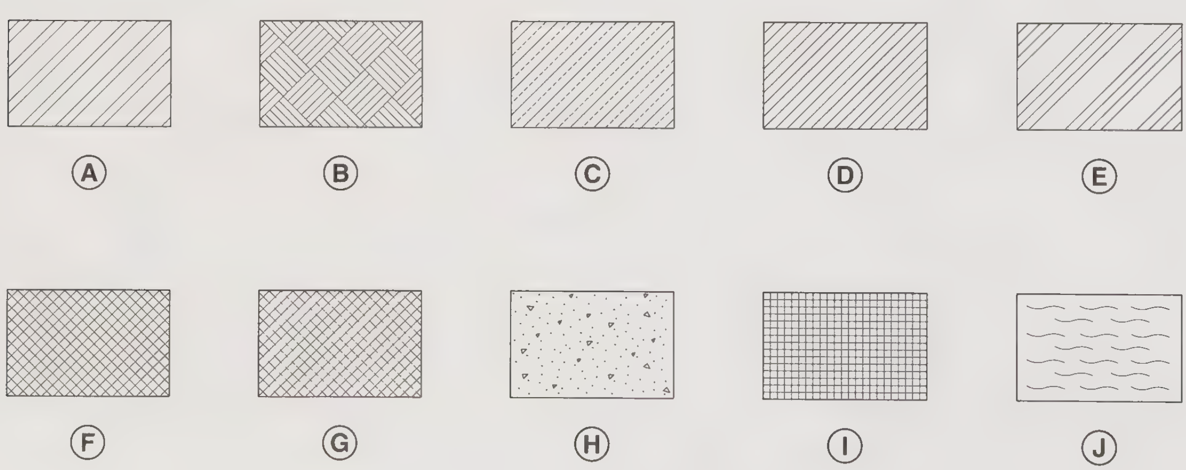
______ 6. Steel

______ 7. Cast Iron and Malleable Iron. Also for general use for all materials.

______ 8. Magnesium, Aluminum, and Aluminum Alloys

______ 9. Electric Windings, Electro-magnets, Resistance, etc.

______ 10. Cork, Felt, Fabric, Leather, and Fiber



◎ .0005 TIR A

Trade Competency Test

Name ________________________ Date ____________

Holder – Punch *(See page 138.)*

_______ **1.** Upon completion, the Holder – Punch is marked _______ on the side.

_______ **2.** The maximum overall diameter of the Holder – Punch is _______″.

_______ **3.** The minimum overall diameter of the Holder – Punch is _______″.

_______ **4.** All internal threads are class _______.

_______ **5.** A(n) _______ section is shown.

_______ **6.** The cutting plane line passes _______ through the centerpoint.

_______ **7.** Surface E must be _______ with surface datum B.

_______ **8.** Surface F is concentric with datum A within a _______″ tolerance zone.

T F **9.** All sharp corners are broke to .020 maximum unless specified.

_______ **10.** The centers of the counterbored holes are _______″ from the centerpoint.

T F **11.** All external corners are chamfered.

T F **12.** An $8\frac{1}{2}''$ × 11″ sheet was used for the original drawing.

_______ **13.** Datum B is _______ to within a .0002 tolerance zone.

_______ **14.** Datum A is _______ to datum B.

_______ **15.** Surface F is perpendicular to datum B within a _______″ tolerance zone.

_______ **16.** The minimum diameter at B is _______″.

_______ **17.** The most critical diameter on the print is shown at _______.

_______ **18.** The Holder-Punch is hardened and drawn to Rc _______.

T F **19.** Hole G is centered a maximum of 1.4375 from datum axis A.

T F **20.** The ∅.750 hole has a maximum allowable depth of 2.237″.

_______ **21.** The overall depth of the Holder – Punch is _______″.

T F **22.** All chamfers are the same size.

T F **23.** Both ∅$\frac{3}{16}$ drills are drilled thru.

T F 24. The maximum distance the center of hole G can vary in any direction is .00025″.

T F 25. Surface F and surface datum A are parallel with each other within .0010″.

_______ 26. The diameter at C is _______″.

_______ 27. A total of _______ holes measuring 11⁄32″ in diameter are drilled through the Holder–Punch.

_______ 28. The maximum diameter at D is _______″.

_______ 29. The minimum diameter at D is _______″.

_______ 30. Hole G is located with reference to datum A at _______ material condition.

Rocker *(See page 138.)*

_______ 1. A(n) _______ section of the Rocker is shown.

_______ 2. The overall height of the Rocker is _______″.

_______ 3. The thickness of the webs is _______″.

_______ 4. The overall depth of the rocker is _______″.

T F 5. All fillets and rounds have a radius of 1⁄8″ unless otherwise specified.

T F 6. The Rocker is symmetrical.

_______ 7. Spotfaced surfaces extend _______″ beyond their base.

_______ 8. The spotfaces are _______″ in diameter.

_______ 9. The diameter at A is _______″.

_______ 10. The thickness of B is _______.

_______ 11. The 1⁄8″ × 3⁄16″ keyway is _______″ in length.

_______ 12. All corners at the base of the Rocker have a(n) _______″ radius.

_______ 13. The overall length of the Rocker is _______″.

T F 14. General use section lining is used to show features cut by the cutting plane.

T F 15. The Rocker is drawn at half scale.

chapter 7

AUXILIARY VIEWS

Auxiliary views show the shape of surfaces that are not parallel to one of the three principal planes. The two types of auxiliary views are primary and secondary auxiliary views.

AUXILIARY VIEWS

Most objects are drawn so that their true shape is projected to the three principal planes of projection. The three principal planes used in orthographic projection are the frontal (vertical) plane, horizontal plane, and the profile plane. These planes are assumed to revolve about axes to bring the various views into a single plane. See Figure 7-1.

The horizontal plane moves about the X-axis and the profile plane moves about the Y-axis. In orthographic projection, these two planes are always revolved into the frontal plane.

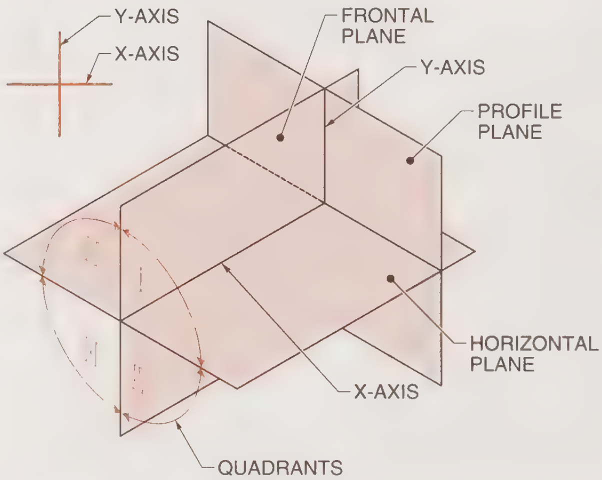


Figure 7-1. Three principal planes are used in orthographic projection.

The intersection of the horizontal and frontal planes generates four quadrants (Quadrants I, II, III, and IV). An object may be placed in any of the four quadrants and its surfaces projected onto the respective planes.

First angle projection is used in European counties. The object is located in Quadrant I and the top view becomes visible on the horizontal plane, the front view on the vertical plane, and the left side on the profile plane. The front view is directly above the top view and the left side view is to the right of the front view. See Figure 7-2.

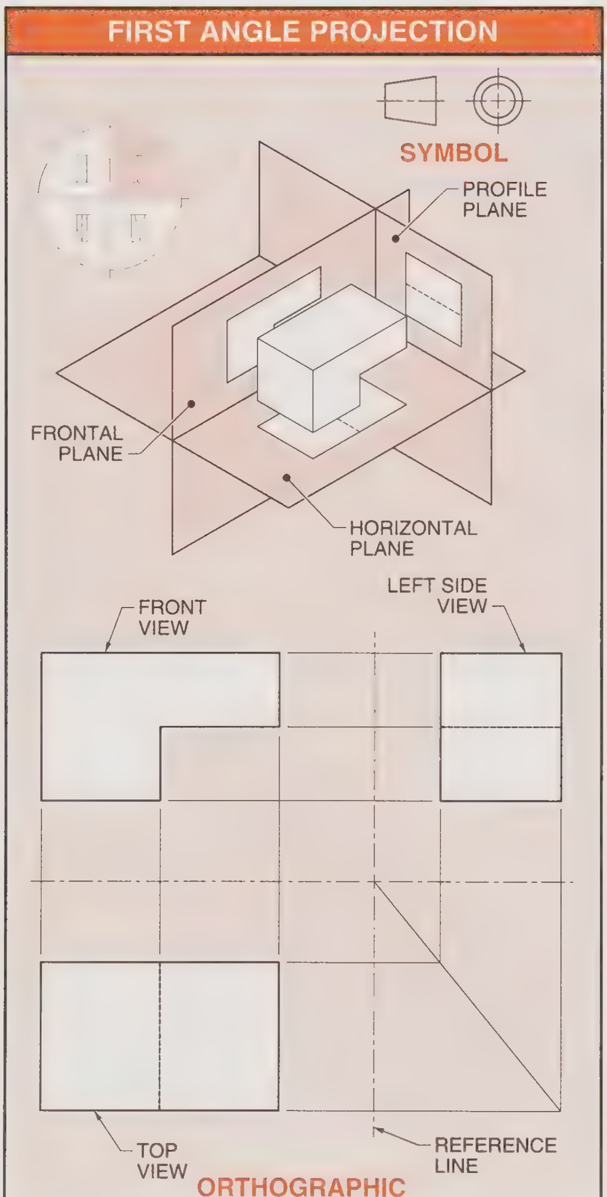


Figure 7-2. Objects are located in Quadrant I in first angle projection.

Third angle projection is used in the United States and Canada. The object is located in Quadrant III and the top view becomes visible on the horizontal plane, the front view on the vertical plane, and the right side view on the profile plane. The horizontal and profile planes are revolved into the frontal planes so that the top view is directly above the front view and the right side view is to the right of the front view as shown in the orthographic. See Figure 7-3.

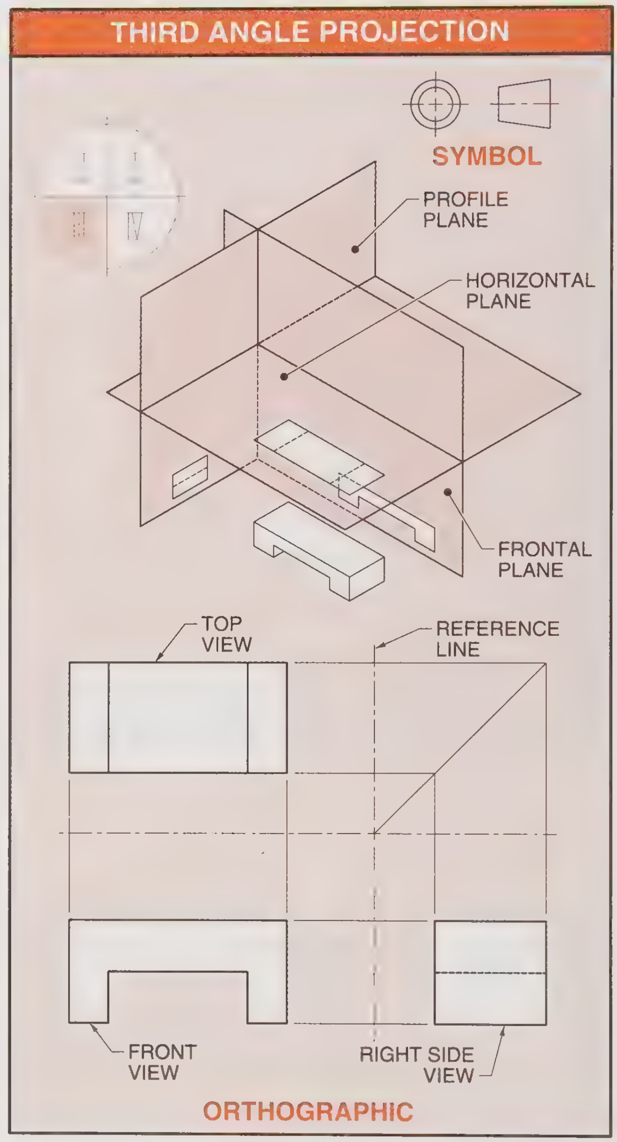


Figure 7-3. Objects are located in Quadrant III in third angle projection.

Objects with surfaces not parallel to one of the three principal planes require auxiliary views to describe the surface. The two types of auxiliary views are primary and secondary auxiliary views.

In prints the representation of an auxiliary view includes only the principal views necessary to complete the auxiliary view. For most objects two principal views usually are sufficient. The complete details of the true shape of the inclined surfaces are then shown on the auxiliary views.

Primary Auxiliary View

A *primary auxiliary view* is a view which is projected to a plane that is perpendicular to one of the three principal planes and inclined to the other two. See Figure 7-4.

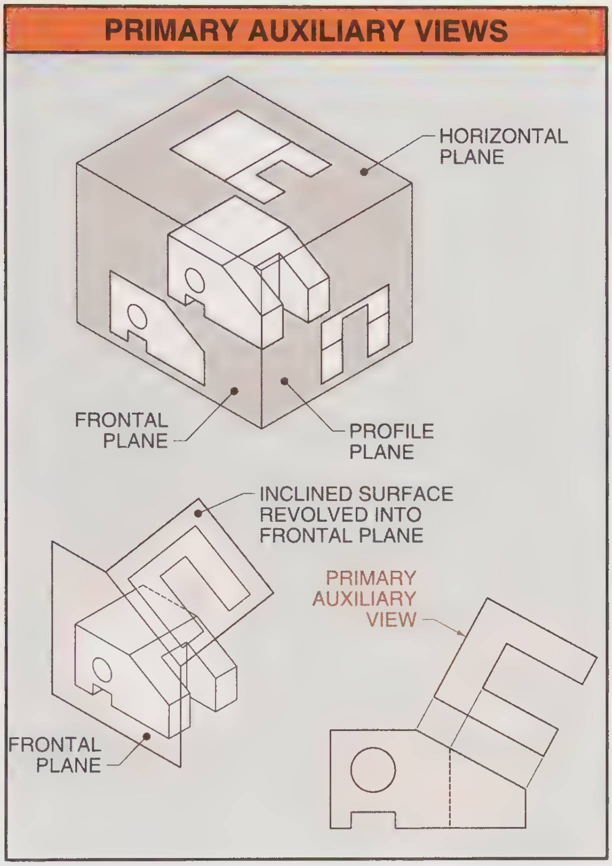


Figure 7-4. A primary auxiliary view is perpendicular to one plane and inclined to the other two.

In this figure, the inclined surface is perpendicular to the frontal plane and inclined to the horizontal and profile planes. The true shape of the slanted surface is obtained only by passing a plane parallel to the inclined surface. This auxiliary plane is then considered to be hinged to the plane to which it is perpendicular and revolved into the frontal plane in much the same way the other views are rotated to their principal planes of projection.

Partial Auxiliary View. In making an auxiliary view, the practice is to show the actual contour of only the inclined surface. The projection of the entire view usually adds very little to the shape description. The additional lines needed to present a complete view often detracts from the true intent of the auxiliary. See Figure 7-5.

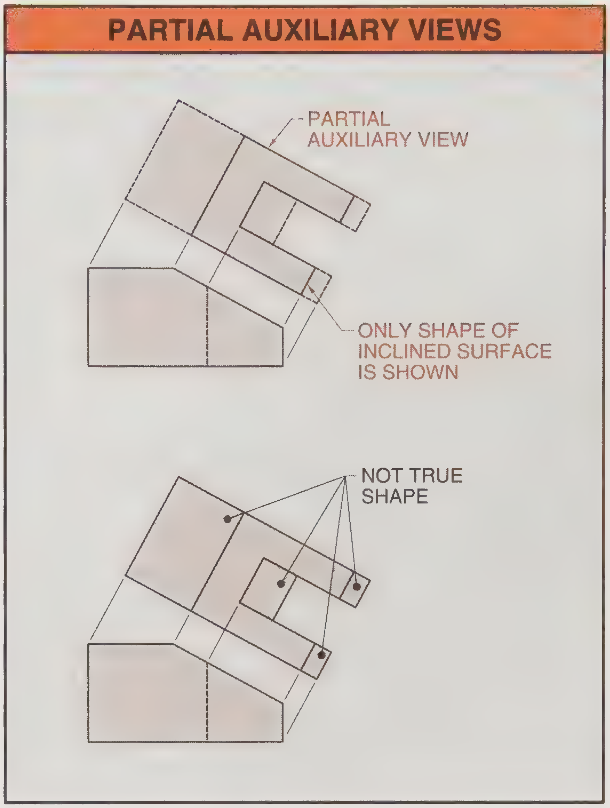


Figure 7-5. Partial auxiliary views show the shape of the inclined surface only.

Primary Auxiliary View Groups. Generally, primary auxiliary views may be classified into three groups – front auxiliary, top auxiliary, and side auxiliary. The views are determined according to the plane to which the auxiliary surface is hinged.

A *front auxiliary view* is a primary auxiliary view that has the inclined surface perpendicular to the frontal plane and is hinged to the frontal plane. A *top auxiliary view* is a primary auxiliary view that has the inclined surface perpendicular to the top plane and is hinged to the top plane. A *side auxiliary view* is a primary auxiliary view that has the inclined surface perpendicular to the side plane and is hinged to the side plane. See Figure 7-6.

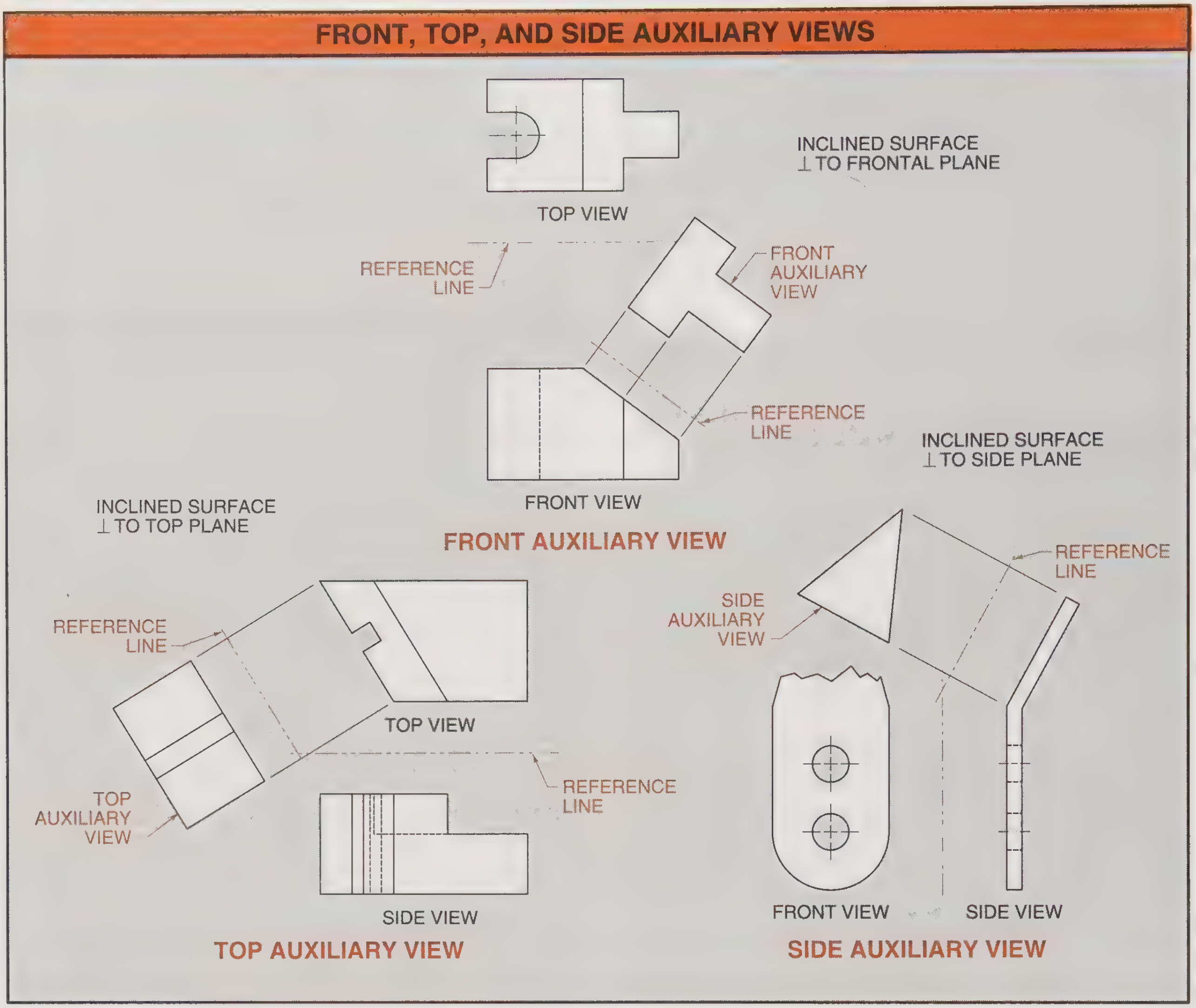


Figure 7-6. Primary auxiliary views are classified according to the plane to which the auxiliary view is hinged.

Symmetrical Auxiliary View. If an auxiliary view is symmetrical, the reference line can serve as a centerline. The auxiliary view is developed from the right and left of this line. A *symmetrical object* is an object with two halves that are mirror images.

To save drawing time, the practice is to include only half of the view. Only one-half is drawn since the other portion is simply a duplication of the part shown. See Figure 7-7.

Elimination of Principal Views

Frequently an auxiliary view permits the elimination of one of the principal views. The general rule is to eliminate a principal view whenever the auxiliary provides sufficient description for a complete understanding of the shape of the part. See Figure 7-8.

Secondary Auxiliary View

A *secondary (double) auxiliary view* is a view which is projected to a plane that is oblique to all of the principal planes. Whereas a primary auxiliary view is always projected from a principal view, a secondary auxiliary view is always projected from a primary auxiliary view.

Whenever the true shape of a surface cannot be shown in either the front, side, or primary auxiliary view, a secondary auxiliary view is necessary. The actual shape of the object is produced

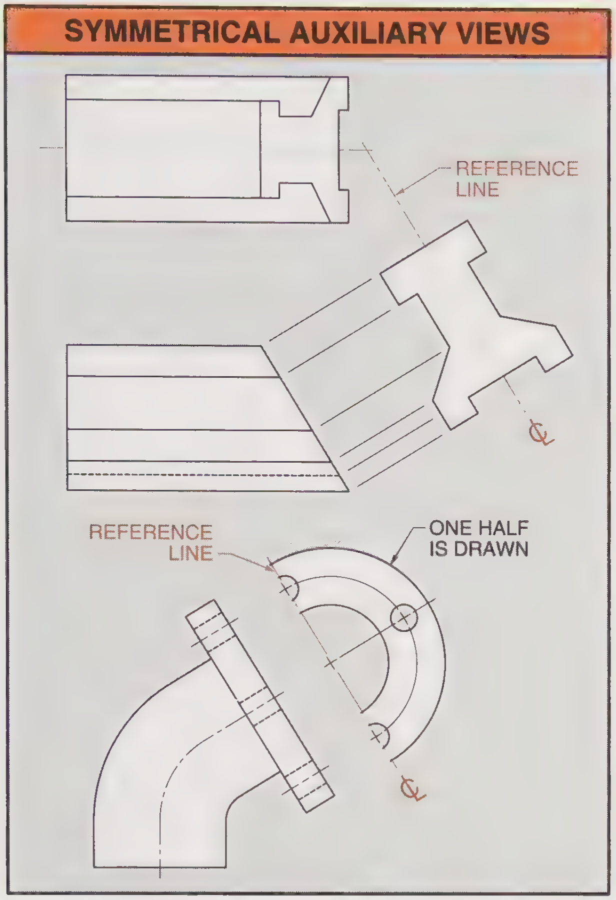


Figure 7-7. In a symmetrical auxiliary, the view is developed from the right and left of the reference line.

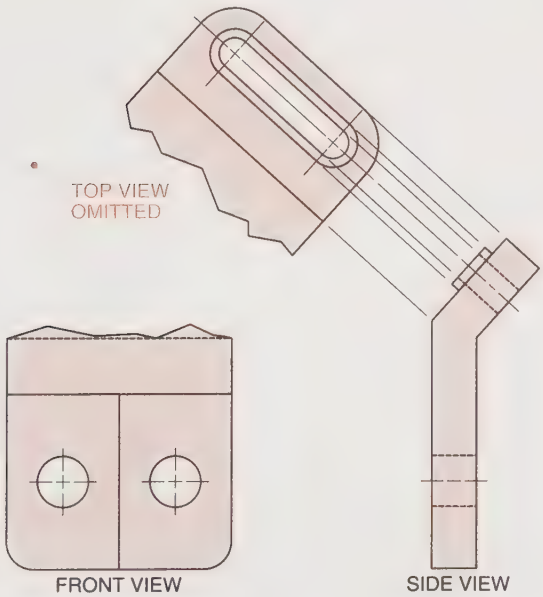


Figure 7-8. An auxiliary often eliminates the need for one of the principal views.

by first drawing a primary auxiliary view and then projecting a double auxiliary view from the primary auxiliary view.

A secondary or double auxiliary view may be projected from a front, top, or side auxiliary view. See Figure 7-9.

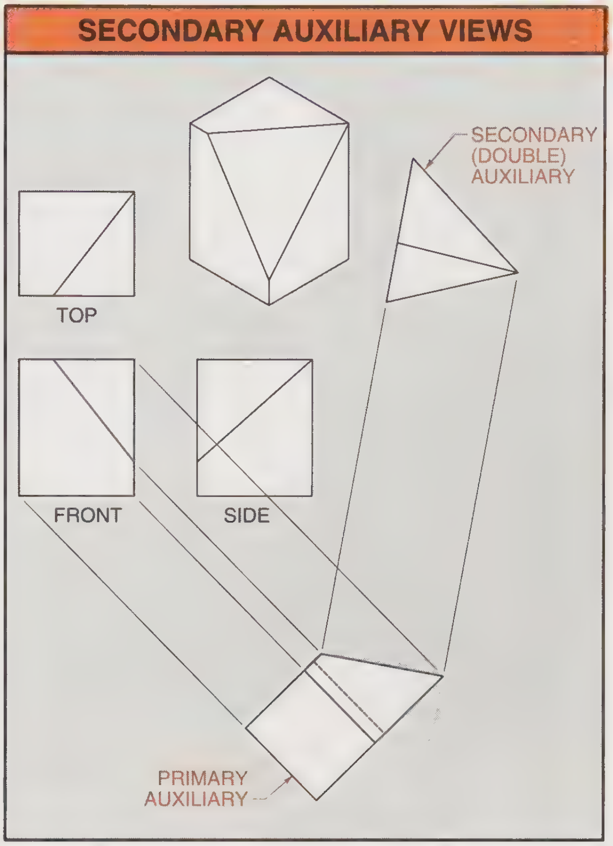
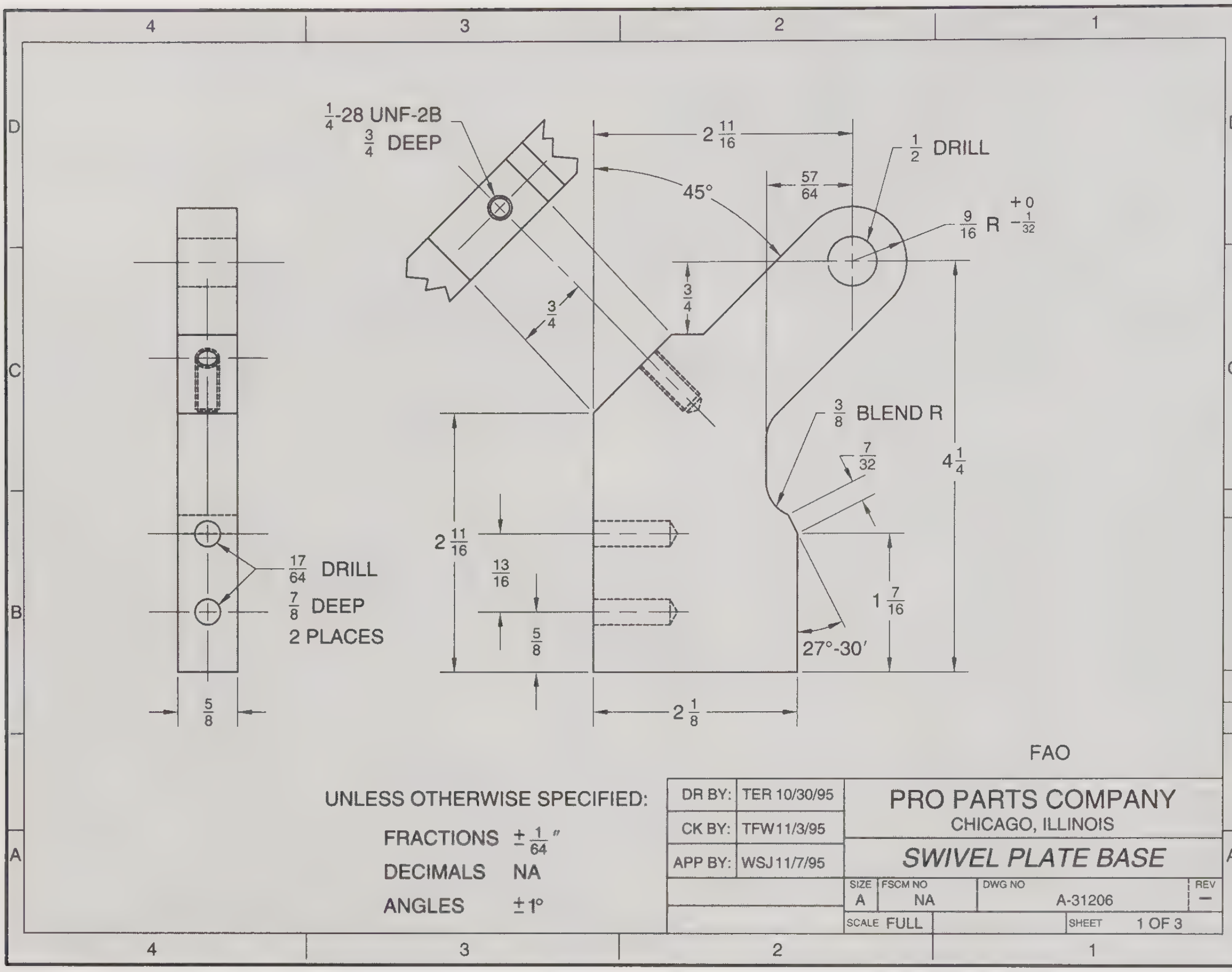


Figure 7-9. A secondary auxiliary view is oblique to all principal planes.



SWIVEL PLATE BASE

Sketching

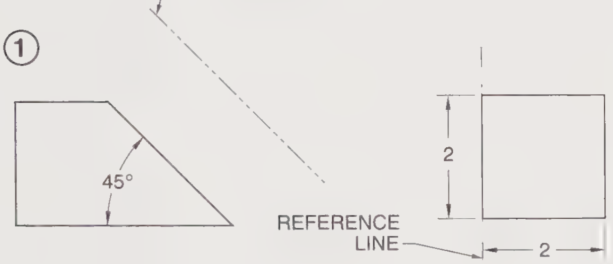
Name ____________________ Date ____________

Sketching — Primary Auxiliary Views

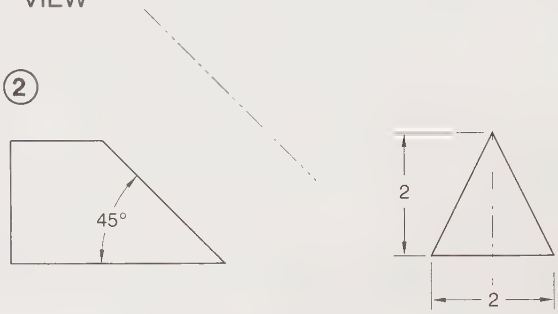
Sketch the frontal auxiliary view.

FRONT VIEW | REFERENCE LINE | RIGHT SIDE VIEW | FRONT VIEW | RIGHT SIDE VIEW

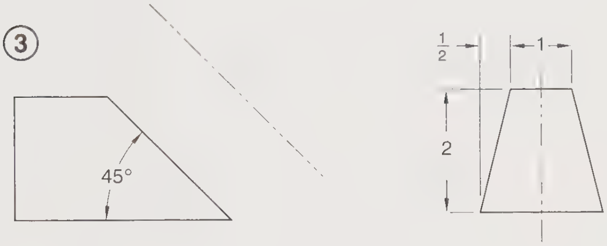
1



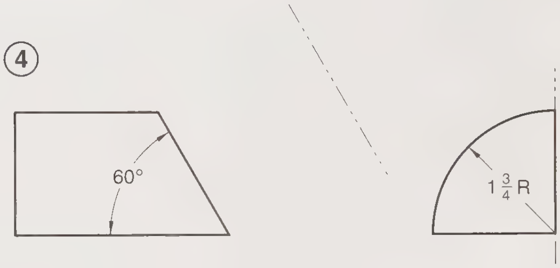
2



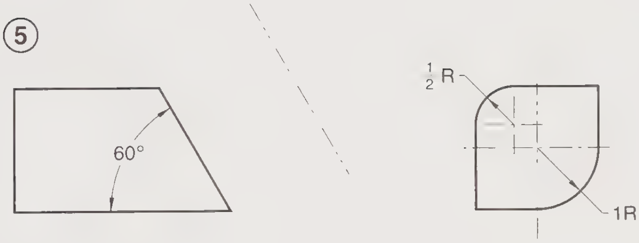
3



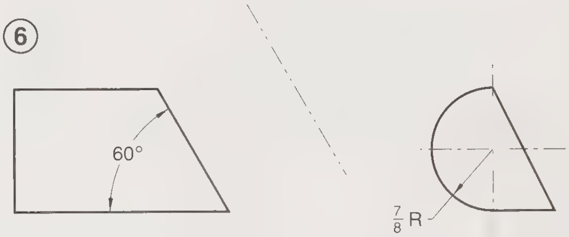
4



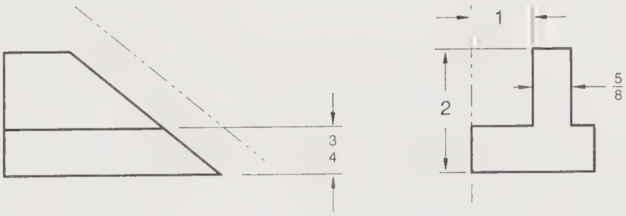
5



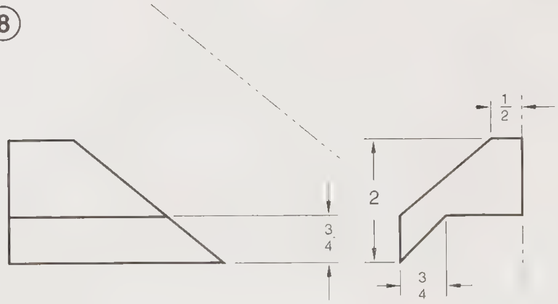
6



7



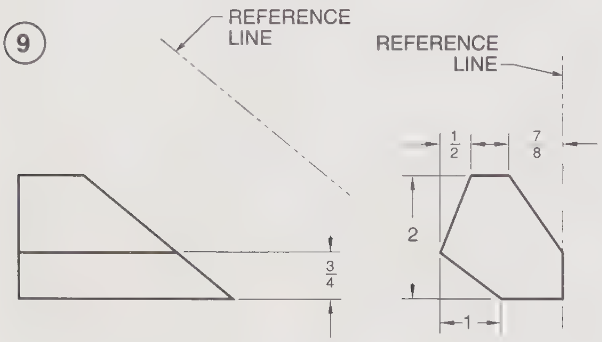
8



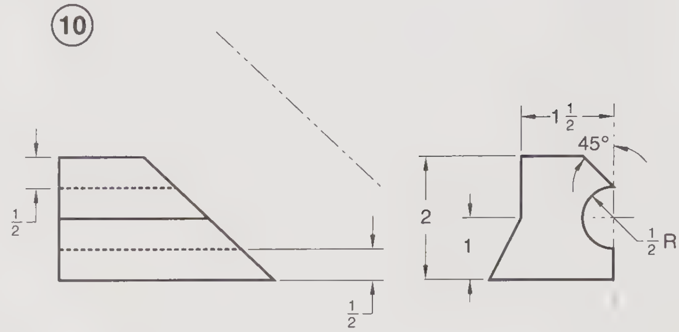
Sketching — Primary Auxiliary Views (continued)

FRONT VIEW | RIGHT SIDE VIEW | FRONT VIEW | RIGHT SIDE VIEW

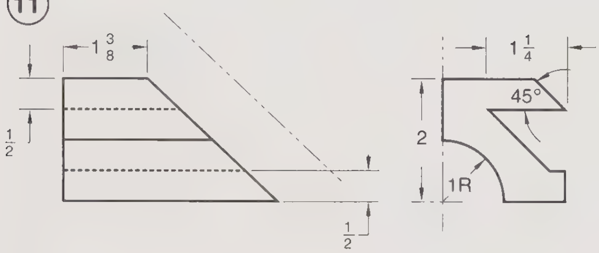
(9)



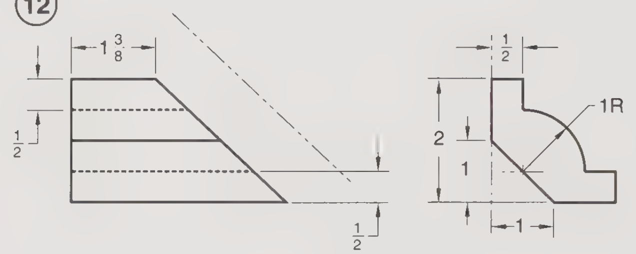
(10)



(11)

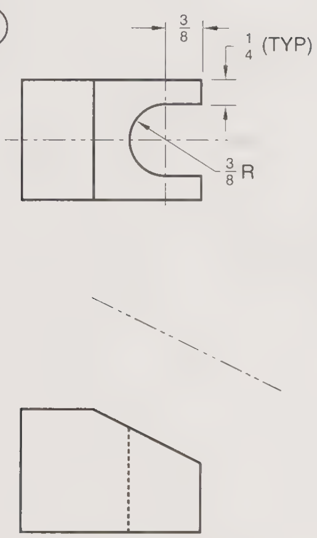


(12)



TOP VIEW

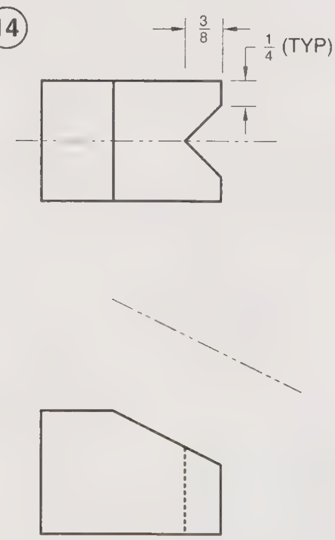
(13)



FRONT VIEW

TOP VIEW

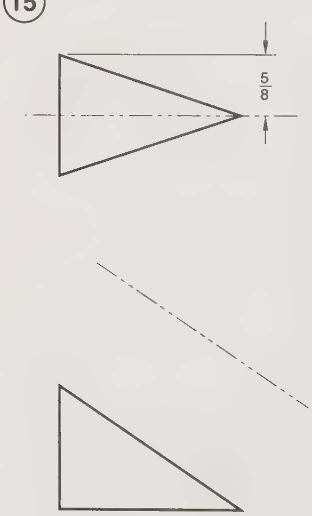
(14)



FRONT VIEW

TOP VIEW

(15)



FRONT VIEW

Ø6 A1

Review Questions

Name ______________________________ Date ______________

Completion

______ **1.** Auxiliary views show the shape of surfaces that are not ________ to one of the three principal planes.

______ **2.** ________ angle projection is used in the United States and Canada.

______ **3.** ________ angle projection is used in European countries.

______ **4.** A(n) ________ auxiliary view is a view projected to a plane perpendicular to one of the three principal planes and inclined to the other two.

______ **5.** In making an auxiliary view, the practice is to show the actual contour of only the ________ surface.

______ **6.** If an auxiliary view is symmetrical, the ________ line can serve as a centerline.

______ **7.** A(n) ________ auxiliary view is projected to a plane that is oblique to all of the principal planes.

______ **8.** Most objects are drawn so that their true ________ is projected to the three principal planes of projection.

______ **9.** The horizontal plane moves about the ________-axis.

______ **10.** The profile plane moves about the ________-axis.

______ **11.** ________ principal views usually are sufficient to show the details of an object.

______ **12.** A(n) ________ auxiliary view has the inclined surface perpendicular to the frontal plane.

______ **13.** The horizontal and profile planes are always moved into the ________ plane in orthographic projections.

______ **14.** A(n) ________ object has two halves that are mirror images.

______ **15.** A primary auxiliary view is always projected from a(n) ________ view.

______ **16.** A secondary auxiliary is always projected from a(n) ________ auxiliary view.

______ **17.** Objects with surfaces not ________ to one of the three principal planes require auxiliary views to describe the surface.

True-False

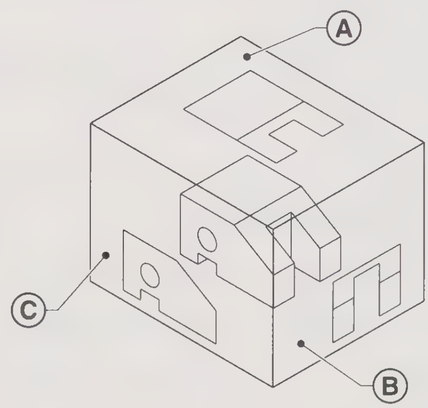
T	F	1. The two types of auxiliary views are primary and secondary views.
T	F	2. In first angle projection, the front view is directly above the top view.
T	F	3. The practice is to include only one-half of a symmetrical view.
T	F	4. A secondary auxiliary view may be projected from a front, top, or side auxiliary view.
T	F	5. The frontal plane is also known as the profile plane.
T	F	6. In third angle projection, the top view is directly above the front view.
T	F	7. An auxiliary view may eliminate the need for one of the principal views.
T	F	8. An object may be drawn in any of the four quadrants.
T	F	9. In third angle projection, the object is located in Quadrant III.
T	F	10. Auxiliary views are developed from a reference line.

Identification — Principal Planes

______ 1. Frontal plane

______ 2. Horizontal plane

______ 3. Profile plane



Identification — Axes and Quadrants

______ 1. X-axis

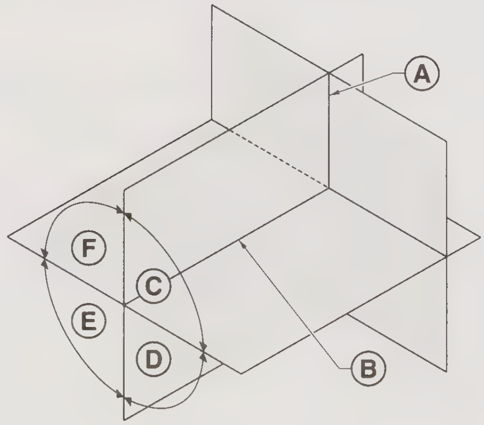
______ 2. Y-axis

______ 3. Quadrant I

______ 4. Quadrant II

______ 5. Quadrant III

______ 6. Quadrant IV



◎ .0005 TIR A

Trade Competency Test

Name ____________________ Date ____________

Swivel Plate Base *(See page 152.)*

_______ **1.** A(n) _________ auxiliary view shows a frontal view of the threaded hole.

A. symmetrical
B. partial
C. secondary
D. double

_______ **2.** The overall height of the Swivel Plate Base is _________″.

_______ **3.** The maximum thickness of the Swivel Plate Base is _________″.

_______ **4.** The minimum thickness of the Swivel Plate Base is _________″.

_______ **5.** A class _________ fit is specified for the drilled hole.

T F **6.** The Swivel Plate Base is finished all over.

T F **7.** The 7/8″ deep holes can be drilled with fractional drills.

_______ **8.** The vertical distance between the two 17/64″ drilled holes is _________″.

_______ **9.** The drawing was checked by _________ on 11-3-95.

_______ **10.** The arm of the Swivel Plate Base is at a(n) _________° angle to the base.

_______ **11.** The 3/8 radius is blended to a 7/32″ flat, which is at a(n) _________ angle to the vertical.

_______ **12.** The scale of the drawing is _________.

_______ **13.** The drawing number is _________.

_______ **14.** The depth of the threaded hole is _________″.

_______ **15.** The center of the 1/2″ drilled hole is _________″ above the base.

_______ **16.** The drawing was approved by _________.

_______ **17.** Pro Parts Company is located in _________, IL

T F **18.** There are three sheets in this set of drawings.

T F **19.** The drawing was completed on a size B sheet.

_______ **20.** All fractional dimensions have a(n) _________″ tolerance zone.

Pressure Clevis

_______ 1. A(n) _________ auxiliary is shown of the Pressure Clevis.

_______ 2. Front and top _________ views of the Pressure Clevis are shown.

_______ 3. The threaded hole is on a surface that is _________° to the top surface.

_______ 4. _________ lines are used to indicate that a full auxiliary is not shown.

_______ 5. A(n) _________ thread form is specified for the threaded hole.

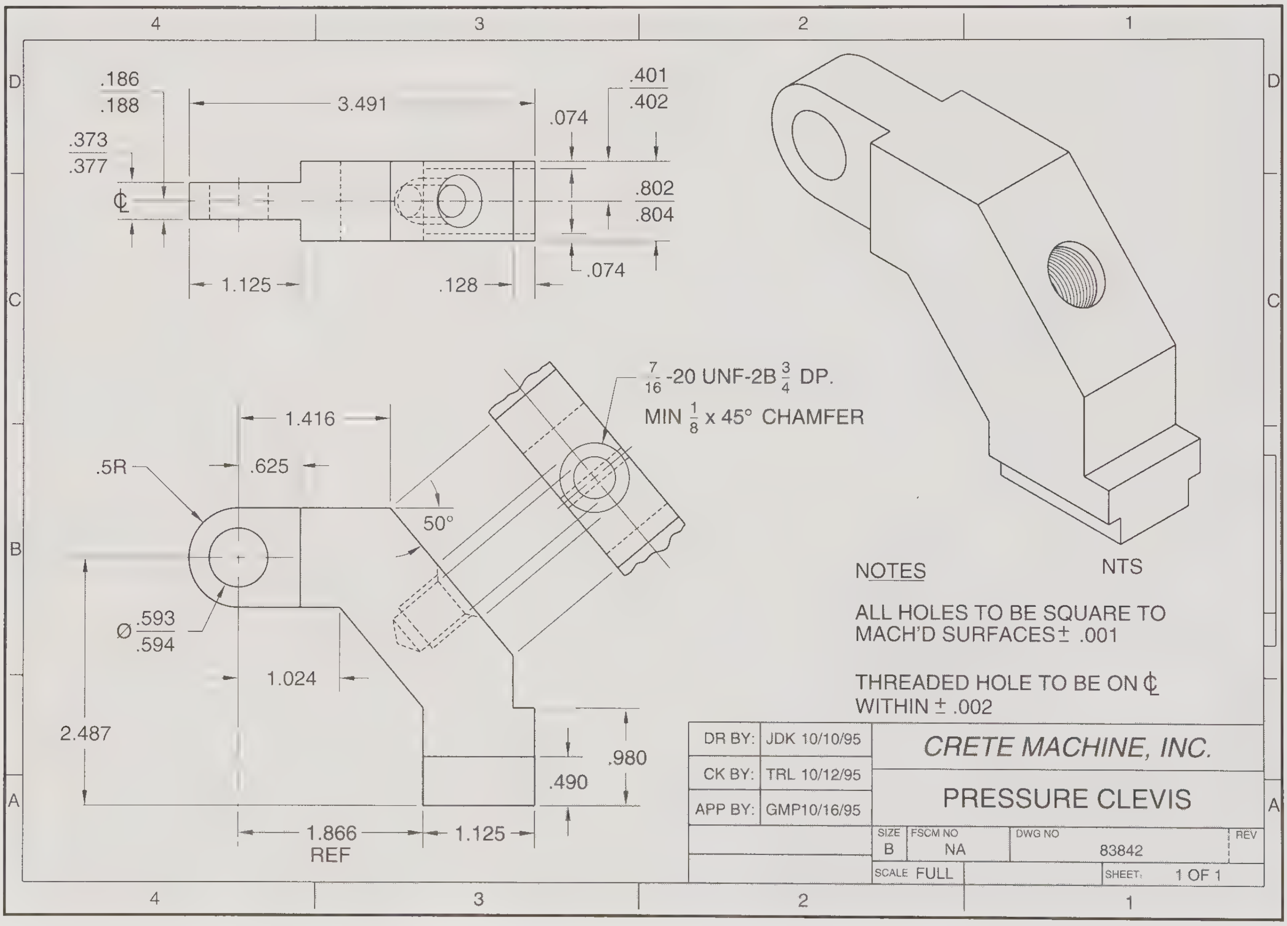
_______ 6. The distance from the centerpoint of the drilled hole to the base is _________″.

_______ 7. The maximum diameter of the drilled hole is _________″.

_______ 8. The overall length of the Pressure Clevis is _________″.

_______ 9. The overall height of the Pressure Clevis is _________″.

_______ 10. All holes are square to the machined surface to _________″.



PRESSURE CLEVIS

chapter 8

DETAIL AND ASSEMBLY PRINTS

Detail and assembly prints are prints used to show either features of a part or how parts fit together. Detail drawings are made to completely describe a part for production. Assembly drawings are made to describe how two or more parts are oriented in relation to each other.

DETAIL PRINTS

Detail prints are prints that provide complete information needed to produce a part. They may include primary, auxiliary, section, or other views of the object. The prints also include needed dimensions, tolerances, notes, etc. so that the part may be manufactured.

Many types of detail drawings are used depending on the complexity of the part. A simple part may require only one or two views to completely describe it. More complex parts may require several auxiliary and/or sectional views. See Figure 8-1. Specific manufacturing methods require prints with different types of detail drawings. In the metal trades, these are prints for patternmaking, forging, welding, stamping, and machining.

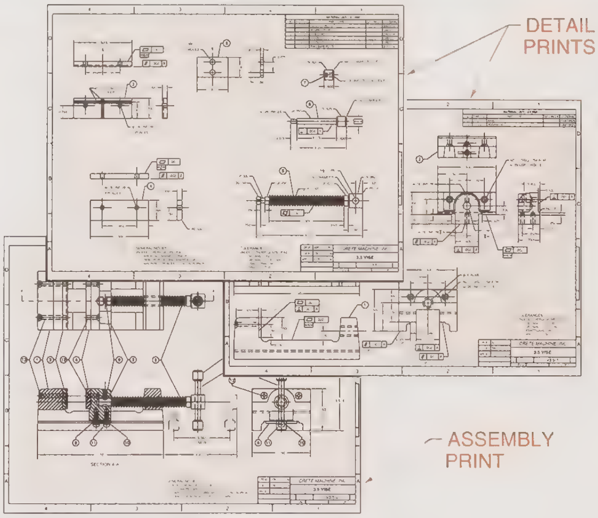


Figure 8-1. Detail prints are required for each part of an assembly.

Patternmaking

Patternmaking prints are prints that detail the information needed to make a pattern for a cast part. These drawings provide size and shape information that takes into account metal shrinkage and machining processes to be completed.

Special features included on the patternmaking print include draft angles, core prints, and parting lines. Only features that are cast into the part are shown. A separate drawing of the finished part is also required. See Figure 8-2.

PATTERNMAKING PRINTS

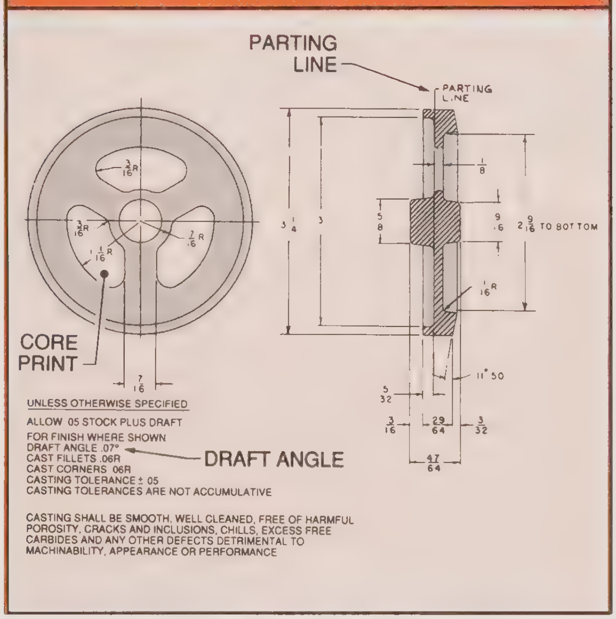


Figure 8-2. Patternmaking prints show features such as draft angle and parting line information.

Forging

Forging prints are prints that describe those elements forged into a part. A separate drawing of the finished part is also required. See Figure 8-3.

If the forging is not extremely complex, a single print may be used to show the forging and machining details. These *composite drawings* are drawings that show the forging detail using phantom lines and the machining detail using object lines. Dimensions are placed on the finished part with the forging sizes being adjusted to allow for shrinkage and machining.

FORGING PRINTS

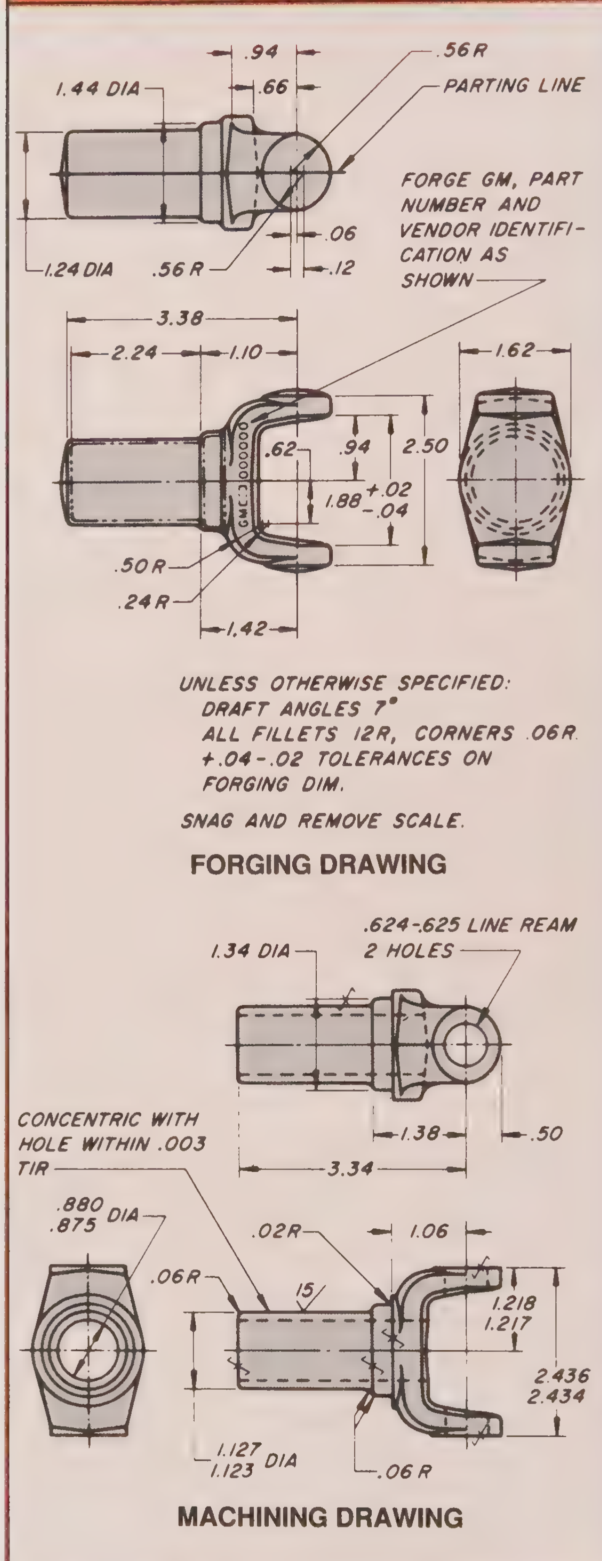


Figure 8-3. Forging prints show features forged into parts while the machining print shows finished detail.

Welding

Welding prints are prints that describe several pieces that are welded together to make the finished part. Each part to be attached is dimensioned. Welding symbols are used to give weld information. See Appendix. A parts list is included to list all parts needed to make the final object. A separate detail of each component part may also be included. See Figure 8-4.

Stamping

Stamping prints are prints that describe thin material parts that are formed under pressure to their final shape. The detail drawings for stamped parts appear essentially the same as machined parts. The primary difference is that tolerances for stamped parts generally allow for greater variance on the breakout side of the stamping. See Figure 8-5. The *breakout side* of a stamped part is the side opposite the die that breaks through the surfaces.

Machining

Machining prints are prints that show the machining information required to produce a part. They show the greatest amount of detail about the size and shape of an object. The manufacturing of a part generally ends with the machining stage. Machining details specify more information about surface finish, tolerances, dimensions, etc. than other types of detail drawings.

Machining details are sometimes simplified to make them easier to understand. See Figure 8-6.

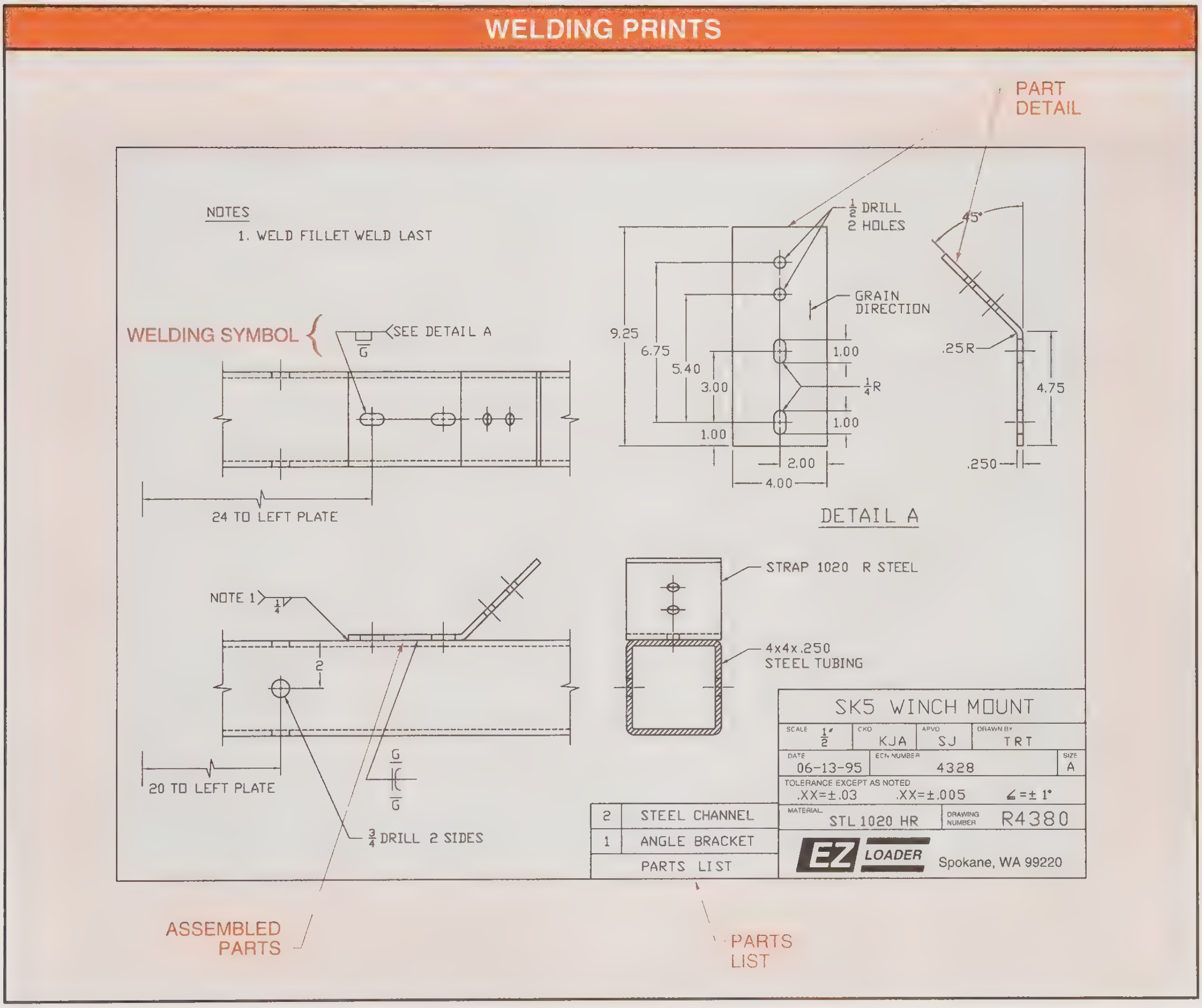


Figure 8-4. Welding prints show assembled parts and may show part details as well.

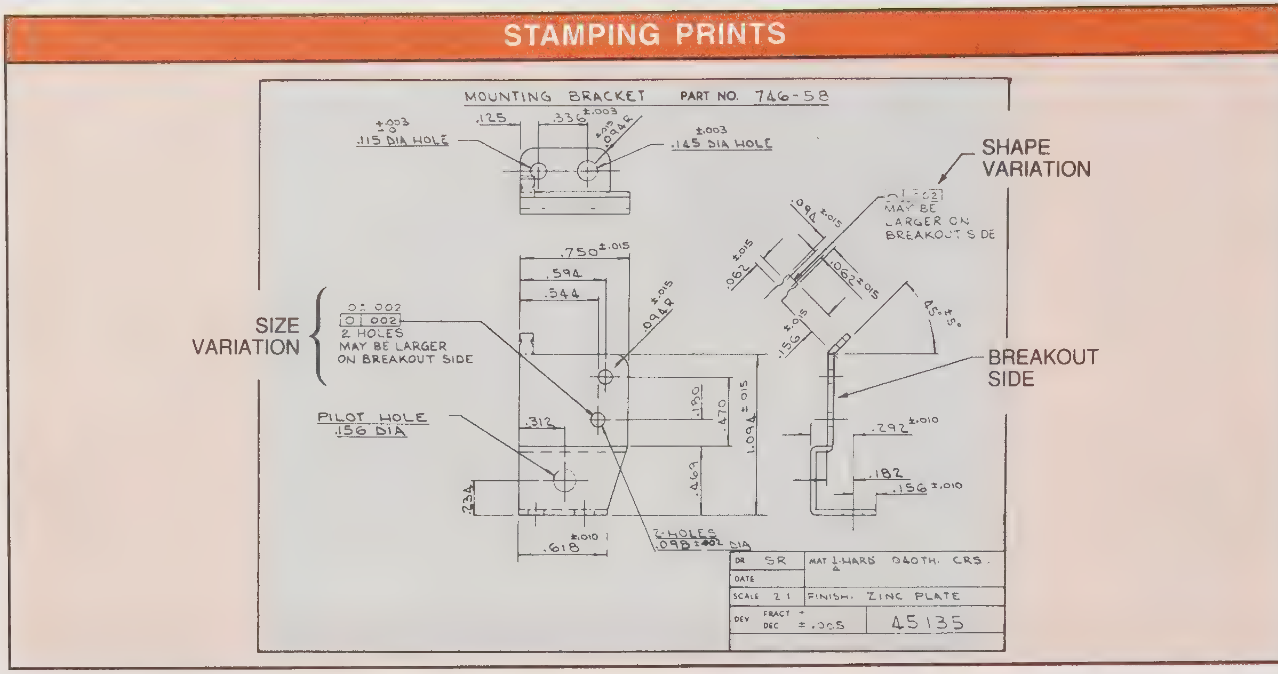


Figure 8-5. Stamping prints allow for size and shape variations on the breakout side.

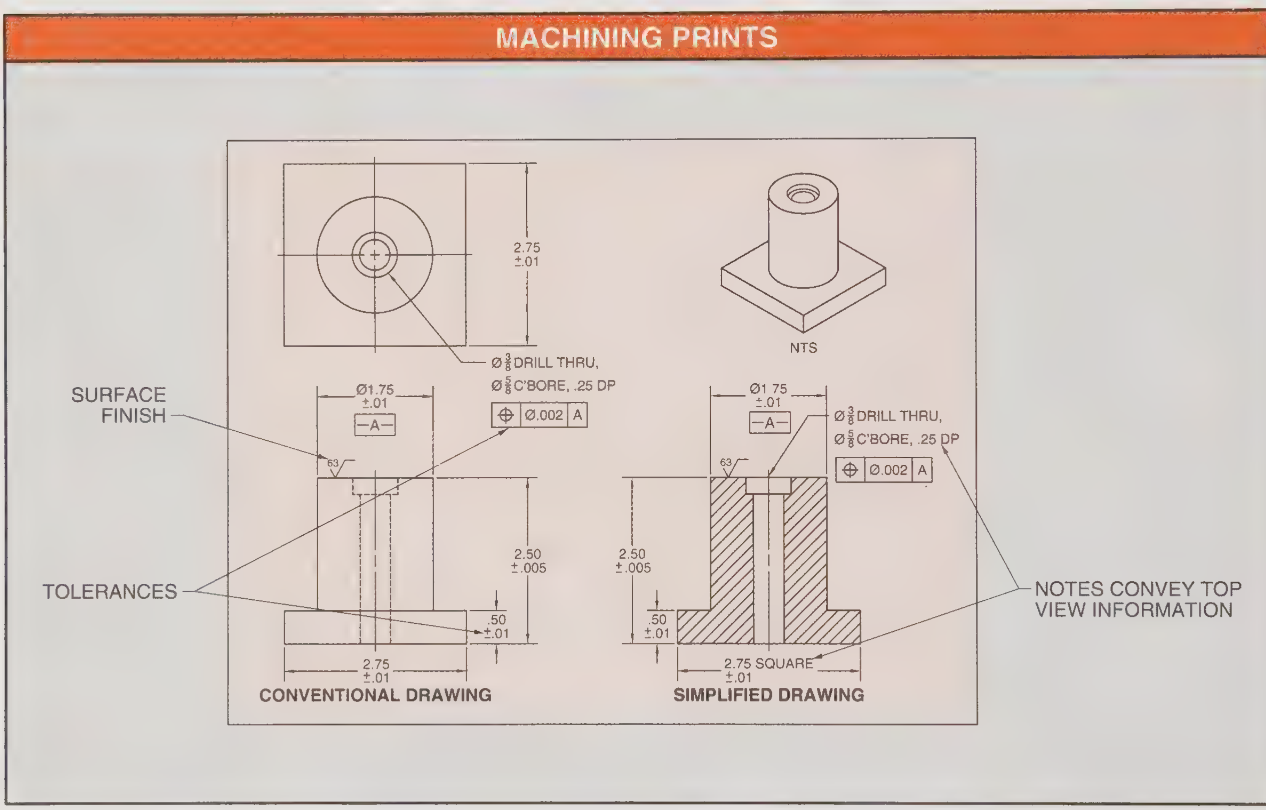


Figure 8-6. Simplified drawings can reduce the number of needed views.

Views may be eliminated. When this is done, notes are placed on the drawing to relay the information the extra view would have contained. These notes may contain information about dimensions or describe a geometric shape. Other symbols may be placed on a drawing to simplify it. These are generally used to identify holes of a common diameter without needing multiple leaders. See Figure 8-7.

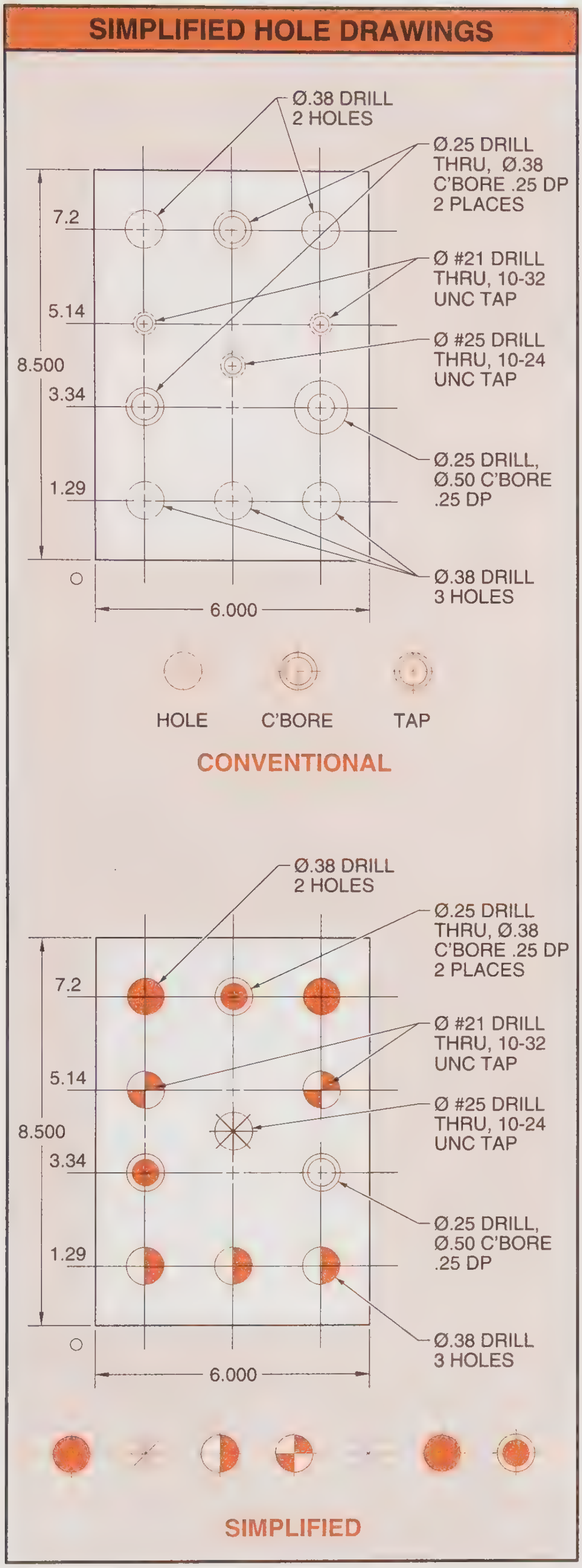


Figure 8-7. Symbols may be used to simplify drawings.

Other ways drawings may be simplified include the elimination of repetitive or hidden lines. Stock items or purchased hardware is not drawn. Unimportant information is omitted. Notes are used to convey what the omitted feature would have shown. Simplified drawings convey all information needed to make the part.

ASSEMBLY PRINTS

Assembly prints are prints that show how two or more parts fit together. The prints identify all parts required for the assembly. These prints also include all detail parts made for the product and purchased parts such as bolts, set screws, keys, etc. Parts are identified on the prints using an encircled number. A leader points from the circle to the part. The numbers relate to the parts list included on the assembly.

Dimensions required to give overall height, width, and depth may be included. Assembly dimensions such as distances between centers or other sizes needed to understand how parts fit and overall sizes may also be included.

Assembly prints may be either orthographic or pictorial representations of the finished assembly. The type of drawing is selected based on the use of the drawing.

Orthographic Assembly Prints

Orthographic assembly prints are representations of parts shown in one or more of the primary planes of projection. The number of views shown is selected in order to completely describe the assembly. Generally, one or two views will suffice. The views are either shown as conventional views or as sectional views. See Figure 8-8. Orthographic assembly prints are used primarily as working assembly drawings in a manufacturing setting.

Detail assembly prints are used on some simple drawings. See Figure 8-9. These combination drawings show both the assembly and the information drawings on a single sheet.

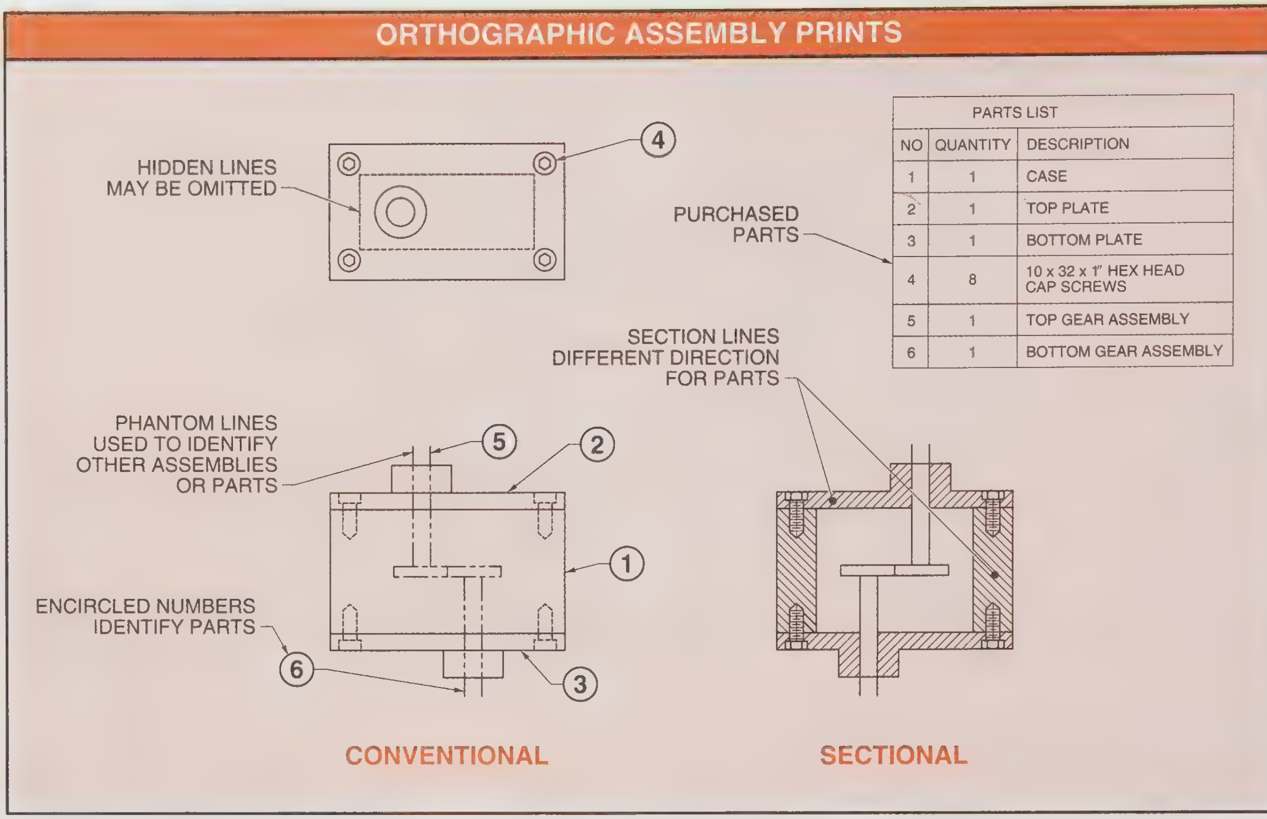


Figure 8-8. Orthographic assembly prints show conventional and/or sectional views of the object.

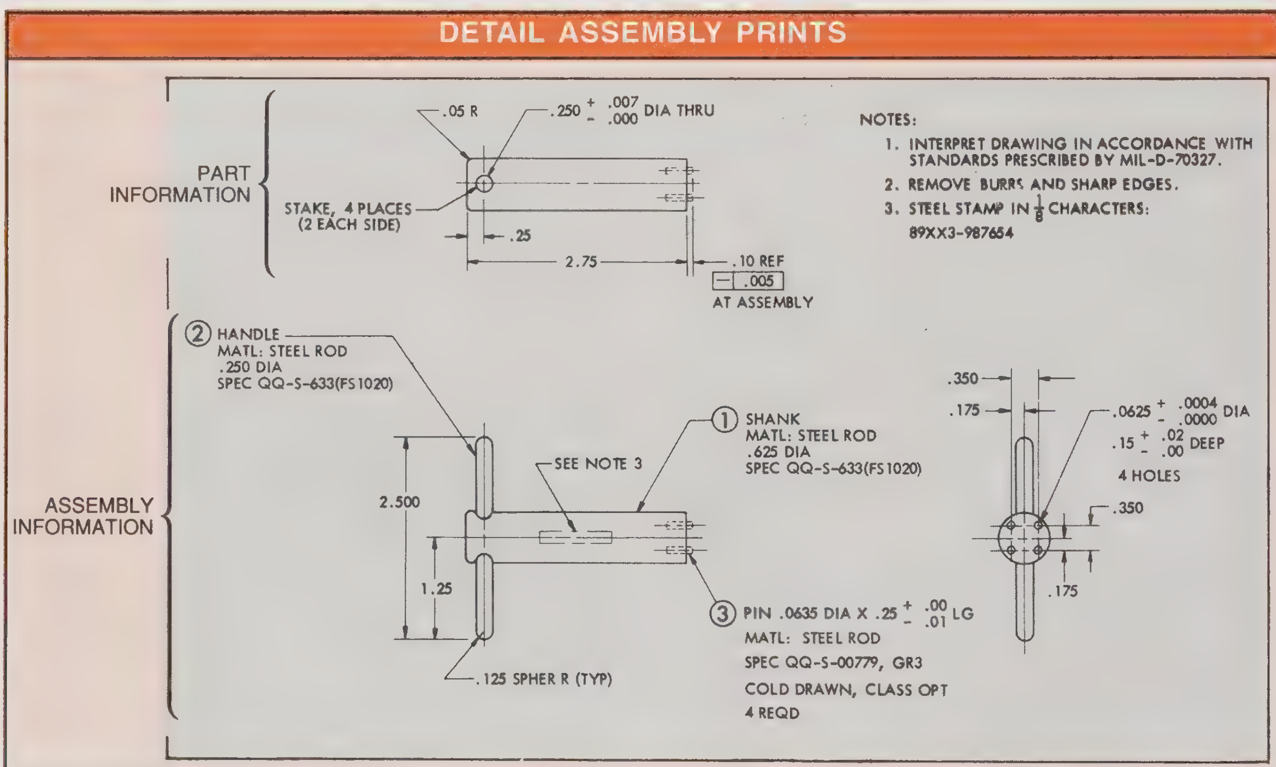


Figure 8-9. Detail assembly prints show both assembly and part information.

Conventional Views. *Conventional views* are orthographic views used to show exterior features of the assembly. Hidden lines are omitted unless they are required to understand the assembly. These drawings are used for simple assemblies with few internal features.

Sectional Views. *Sectional views* are orthographic views used to show internal features of the assembly. The section lines are drawn at various angles to differentiate parts in the assembly. These drawings are used for more complex drawings, and drawings with many parts.

Pictorial Assembly Prints

Pictorial assembly prints are prints made to represent the assembly as it appears in three dimensions. These are generally drawn as isometric or perspective representations.

Pictorial assembly drawings are used in parts catalogs and technical manuals to provide a clear description of how parts are arranged in an assembly. Sectioned parts may be included to show internal features. See Figure 8-10.

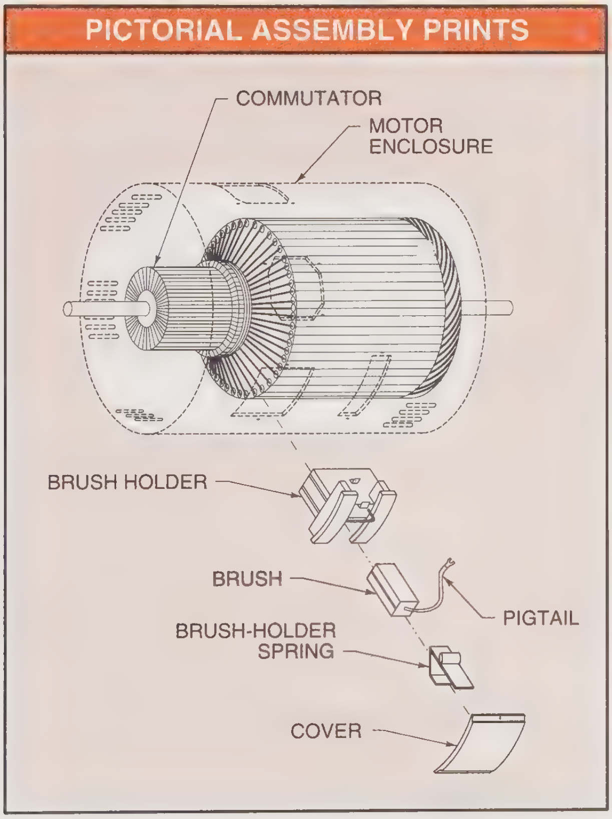
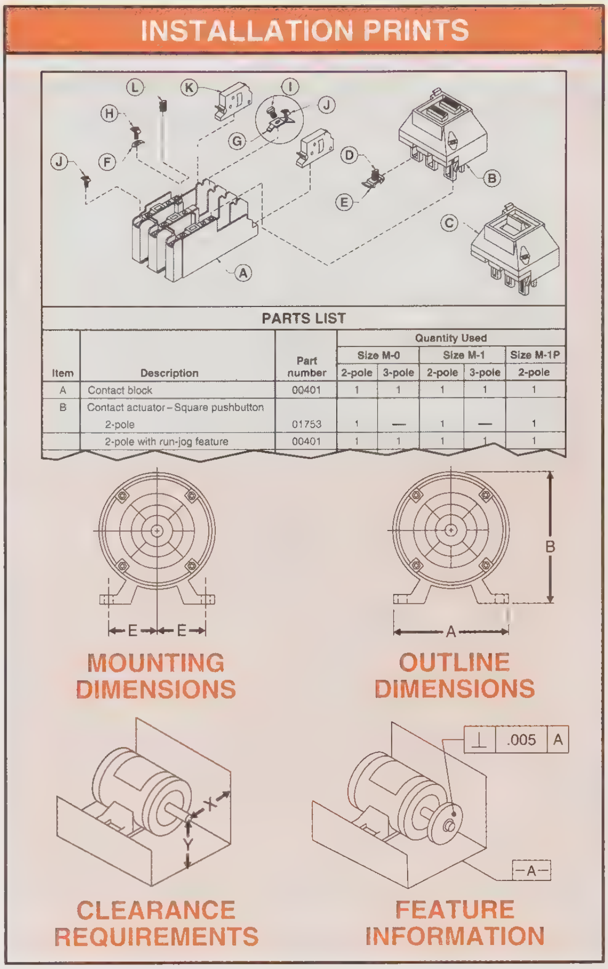


Figure 8-10. Pictorial assembly prints show how parts relate to each other.

Specialized Assembly Prints

Specialized assembly prints are used to show installations or schematics. *Installation prints* are prints that outline the general configuration and information needed to install a piece of equipment. See Figure 8-11. Mounting dimensions, outline dimensions, clearance requirements, and feature information may be included.



PARTS LIST

Item	Description	Part number	Quantity Used: Size M-0, 2-pole	Size M-0, 3-pole	Size M-1, 2-pole	Size M-1, 3-pole	Size M-1P, 2-pole
A	Contact block	00401	1	1	1	1	1
B	Contact actuator – Square pushbutton						
	2-pole	01753	1	—	1	—	1
	2-pole with run-jog feature	00401	1	1	1	1	1

Figure 8-11. Installation prints give information required for a specific piece of equipment.

Mounting Dimensions. *Mounting dimensions* are dimensions used to locate holes or threads for screws, studs, brackets, or clips.

Outline Dimensions. *Outline dimensions* are dimensions that indicate the minimum space required to install the piece of equipment. They show the extreme limits of operation and contours or surfaces related to the mounting dimensions.

Clearance Requirements. *Clearance requirements* are specifications of the servicing and functional space required for the piece of equipment. Clearances are given for all servicing areas such as brushes, covers, etc. Functional clearances cover all extremes of extended and retracted positions, angles of operation, etc.

Feature Information. *Feature information* includes any information required for installation of equipment. This may include the location of keyways, electrical requirements, special rigging, etc.

Schematic Assembly Prints

Schematic assembly prints are prints that show in pictorial or plan view the erection or installation of equipment. These drawings are not made to scale. They may show an electrical or hydraulic circuit, a piping layout, or other such drawings. The only dimensions indicated on these drawings are distances between critical points needed for installation. See Figure 8-12.

SCHEMATIC ASSEMBLY PRINTS

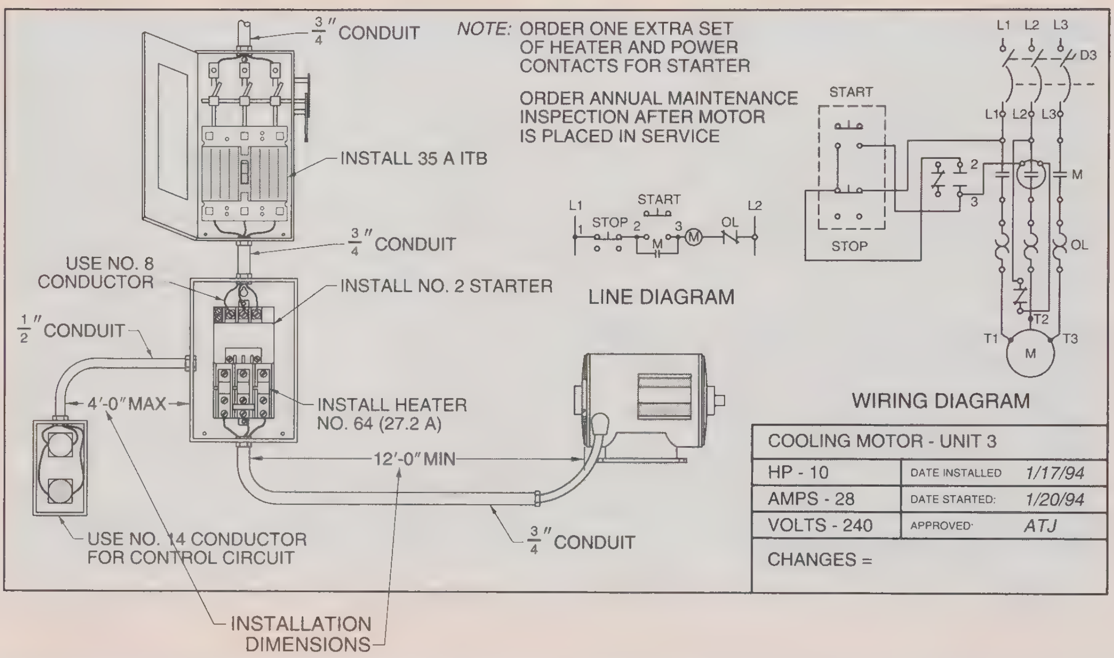


Figure 8-12. Schematic assembly prints show installation dimensions.

Ø6
A1

Review Questions

Name ______________________________ Date ______________

Completion

______ 1. Detail prints completely describe a part for ________.

______ 2. A cast part requires both a patternmaking print and a print of the ________ part.

______ 3. Machining prints show the ________ amount of detail about an object.

______ 4. Assembly prints show how two or more parts ________.

______ 5. Parts on an assembly print are each identified with a(n) ________ number.

______ 6. Orthographic assembly prints are shown as conventional and ________ views.

______ 7. For simple assemblies with few internal features, a(n) ________ view is used.

______ 8. Pictorial assembly prints are drawn as isometric or ________ views.

______ 9. Specialized assembly prints show installations or ________.

______ 10. ________ assembly prints show electrical circuits, piping layouts, etc.

Multiple Choice

______ 1. Detail prints are orthographic drawings with ________.

A. sectional views
B. auxiliary views
C. primary views
D. A, B, and C

______ 2. Patternmaking prints are drawn to make a pattern for ________ parts.

A. forged
B. cast
C. welded
D. machined

______ 3. Composite drawings show ________ details.

A. machining
B. forging
C. both A and B
D. neither A nor B

______ 4. Welding prints contain ________.

A. part details
B. assembly information
C. both A and B
D. neither A nor B

______ 5. Simplified machining prints ______.

A. eliminate views
B. use notes where needed
C. use symbols to replace drawings
D. A, B, and C

______ 6. Stock items are ______ in a simplified drawing.

A. not drawn
B. shown in the outline only
C. used in the assemblies
D. neither A, B, nor C

______ 7. Machining prints show information about ______.

A. surface finish
B. tolerances
C. material
D. A, B, and C

______ 8. Orthographic assembly prints are used primarily in ______.

A. catalogs
B. manufacturing
C. consumer goods
D. exploded drawings

______ 9. ______ dimensions are used to locate holes, studs, and brackets.

A. Clearance
B. Mounting
C. Outline
D. Feature

______ 10. A(n) ______ dimension is the minimum space required for part installation.

A. clearance
B. mounting
C. outline
D. feature

______ 11. Feature information shows dimensions for the ______.

A. location of keyways
B. electrical requirements
C. special rigging
D. A, B, and C

______ 12. Patternmaking prints show ______.

A. finished sizes
B. machined features
C. draft angles
D. thread sizes

True-False

T F 1. Forging prints describe elements in forged parts using phantom lines.

T F 2. A welding print contains a parts list to show all assembled parts.

T F 3. Stamping prints have different tolerances on each side of the part.

T F 4. Simplified machining prints convey less information about the finished part.

T F 5. Stamping prints describe thin parts formed under pressure.

T F 6. All numbered parts are specified on the parts list.

T F 7. Detail assembly prints show part details as well as assembly information.

T F 8. Sectional view assemblies show internal features.

T F 9. Sectioned parts are never used in pictorial assemblies.

T F 10. Schematic prints are drawn to scale.

◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Wire EDM *(See pages 171 and 172.)*

T F **1.** The assembly was drawn before the detail was completed.

______ **2.** The Top 'V' Block has a maximum height of ________″.

A. 4.00 C. 4.005
B. 4.0025 D. 4.03

______ **3.** The final assembly contains ________ different parts.

A. three C. five
B. four D. ten

T F **4.** The drawing number is stamped into the surface of the Top 'V' Block.

______ **5.** The Top 'V' Block may be ________″ thick.

A. .370 – .375 C. .3725 – .3775
B. .370 – .380 D. .375 – .380

______ **6.** The slot has a nominal width of ________″.

______ **7.** The position for the dowel pin holes are accurate to a tolerance of ________″.

A. ±.0005 C. ±.01
B. ±.005 D. ±.03

______ **8.** The distance of A is ________″.

A. .240 C. .250
B. .245 D. .255

T F **9.** Part 2 in the assembly is press fit into Part 1.

______ **10.** All nuts, screws, and bolts are made of ________.

T F **11.** Part 3 has a metric thread.

T F **12.** The slot at C is centered around an axis 2.00″ from the bottom of the Top 'V' Block.

______ **13.** The dimension at B cannot be larger than ________″.

______ **14.** Angle E can be within a range of ________.

A. 118½° – 120½° C. 119°30′ – 120°30′
B. 119° – 121° D. 120° – 121°

________ **15.** The gauge at D has a diameter of ________".

A. 1.338 ± .000
B. 1.338 ± .005
C. 1.338 ± .03
D. not shown on print

________ **16.** The gauge at D locates the center of ________ holes.

A. one
B. two
C. three
D. four

________ **17.** Part G is ________ long.

A. ¼"
B. ¾"
C. 20 mm
D. 1⅛"

________ **18.** Part H is ________ long.

A. ¼"
B. ¾"
C. 20 mm
D. 1⅛"

________ **19.** The radius of the corner at F is ________".

A. .125
B. .25
C. .38
D. any convenient radius

T F **20.** Holes on the detail part are drawn using an exact representation of their appearance.

T F **21.** The assembly drawing is referenced on the detail drawing.

T F **22.** All surfaces are ground to a final finish.

________ **23.** The Top 'V' Block is drawn at ________ scale.

T F **24.** All hidden lines are shown in the right side view of the Top 'V' Block.

T F **25.** There are two HEX HD. SCR. #10-24 × 1⅛ LG. required for the assembly.

________ **26.** The drawings were completed by ________.

________ **27.** Three-place decimal dimensions are accurate to ± ________".

T F **28.** The assembly print has the same tolerances as the detail print.

T F **29.** The assembly drawing number is B-803-28531.

________ **30.** The minimum dimension from the center to the top of the 'V' Block is ________".

A. 1.94
B. 1.97
C. 2.00
D. 2.03

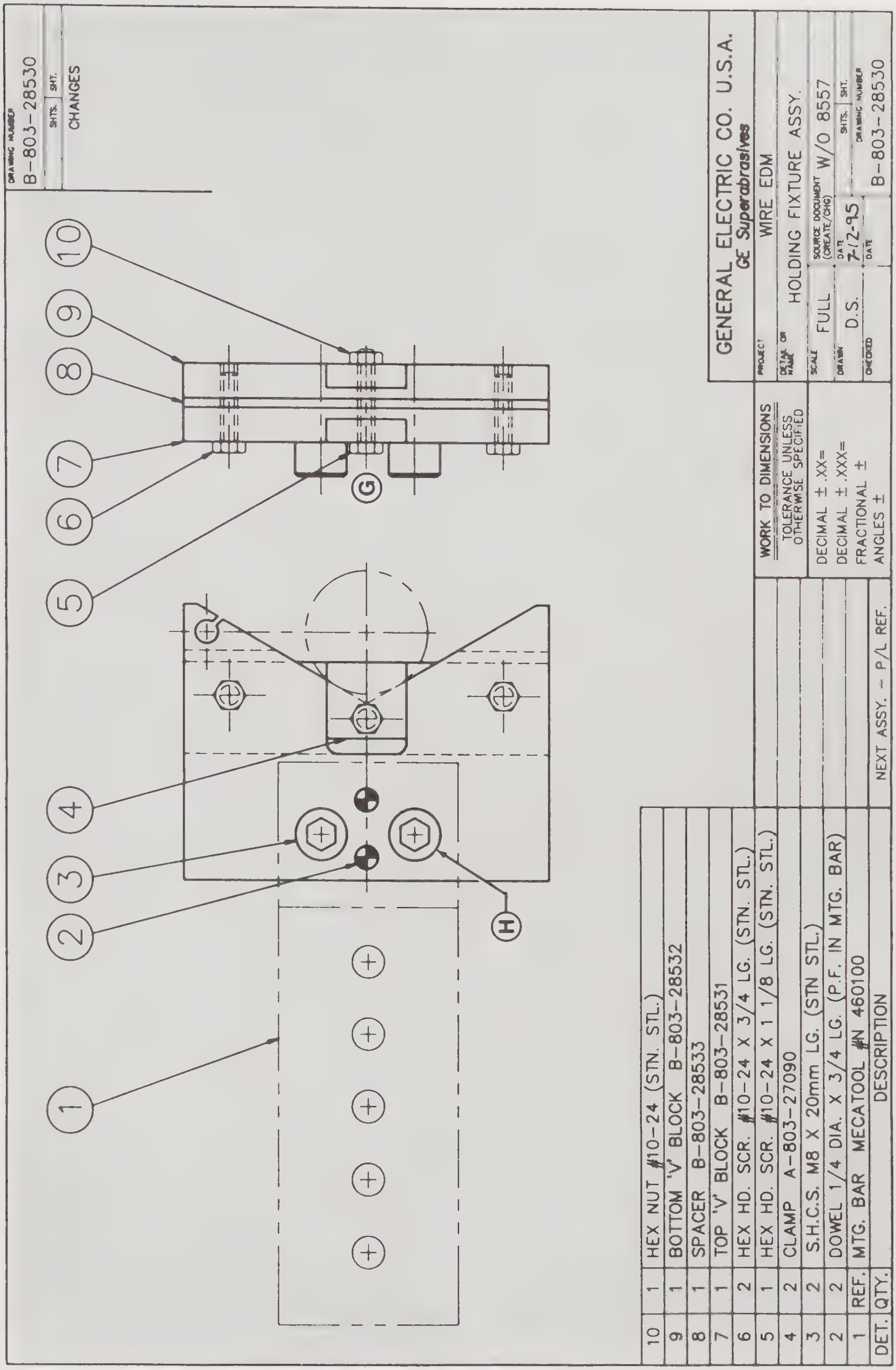
________ **31.** The detail was completed on ________.

________ **32.** The location tolerance for the holes in the Top 'V' Block to locate the dowel pins is ±________".

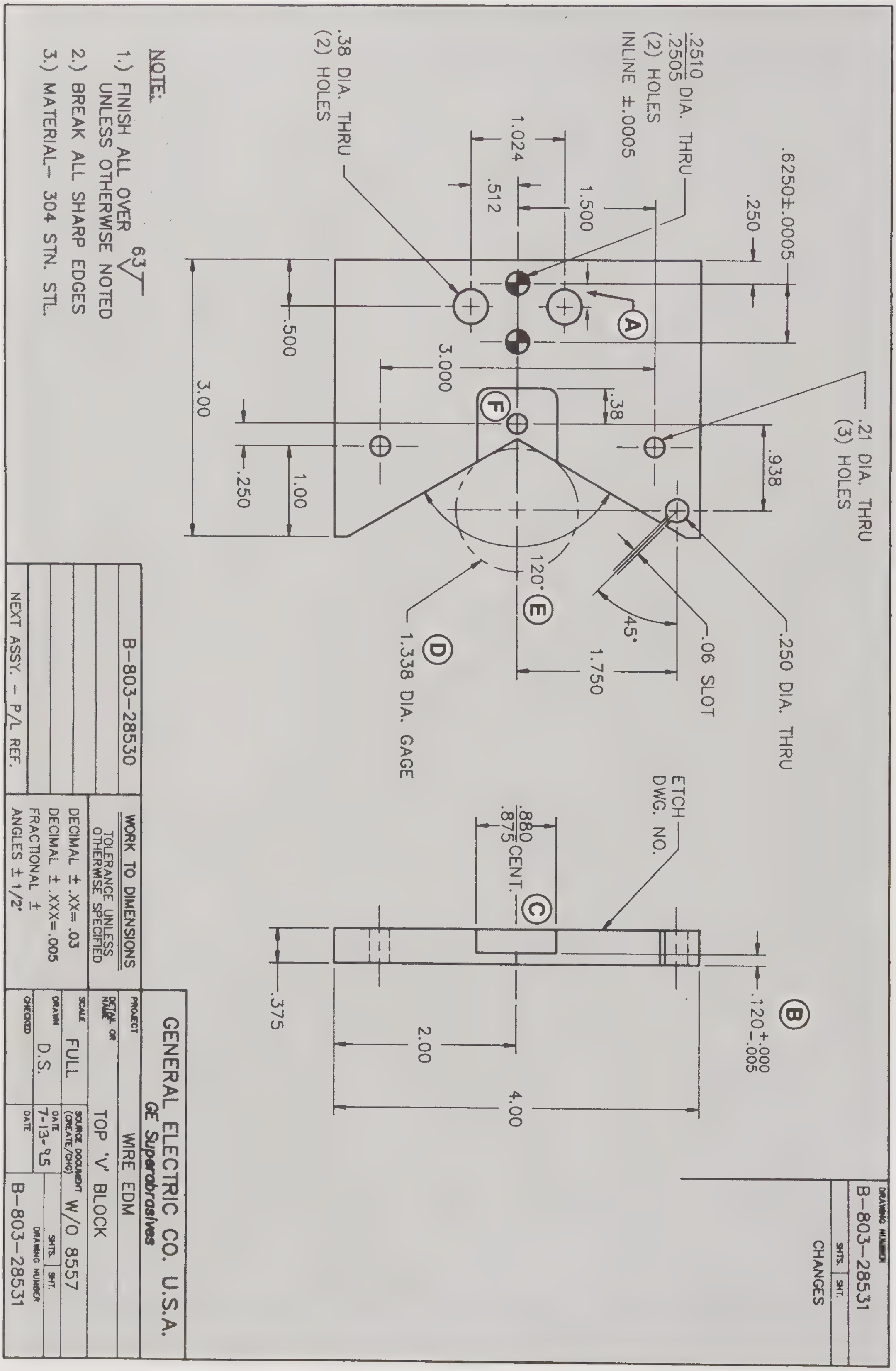
________ **33.** The Top 'V' Block is made from ________.

T F **34.** Angles are accurate to ± ½°.

________ **35.** Part 1 references Mecatool #________.


DRAWING NUMBER B-803-28530
SHTS. SHT.
CHANGES
1
2
3
4
5
6
7
8
9
10
G
H
10 1 HEX NUT #10-24 (STN. STL.)
9 1 BOTTOM 'V' BLOCK B-803-28532
8 1 SPACER B-803-28533
7 1 TOP 'V' BLOCK B-803-28531
6 2 HEX HD. SCR. #10-24 X 3/4 LG. (STN. STL.)
5 1 HEX HD. SCR. #10-24 X 1 1/8 LG. (STN. STL.)
4 2 CLAMP A-803-27090
3 2 S.H.C.S. M8 X 20mm LG. (STN STL.)
2 2 DOWEL 1/4 DIA. X 3/4 LG. (P.F. IN MTG. BAR)
1 REF. MTG. BAR MECATOOL #N 460100
DET. QTY. DESCRIPTION
NEXT ASSY. – P/L REF.
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
DECIMAL ± .XX=
DECIMAL ± .XXX=
FRACTIONAL ±
ANGLES ±
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
PROJECT WIRE EDM
DETAIL OR NAME HOLDING FIXTURE ASSY.
SCALE FULL
SOURCE DOCUMENT (CREATE/CHG) W/O 8557
DRAWN D.S.
DATE 7-12-95
SHTS. SHT.
CHECKED
DATE
DRAWING NUMBER B-803-28530

WIRE EDM


.6250±.0005
.250
.2510/.2505 DIA. THRU
(2) HOLES
INLINE ±.0005
.38 DIA. THRU
(2) HOLES
1.024
.512
1.500
A
.500
3.000
3.00
.38
F
.21 DIA. THRU
(3) HOLES
.938
1.00
.250
120°
E
D
1.338 DIA. GAGE
45°
1.750
.06 SLOT
.250 DIA. THRU
ETCH
DWG. NO.
.880/.875 CENT.
C
B
.120 +.000/-.005
.375
2.00
4.00
NOTE:
1.) FINISH ALL OVER 63
UNLESS OTHERWISE NOTED
2.) BREAK ALL SHARP EDGES
3.) MATERIAL– 304 STN. STL.
B–803–28530
NEXT ASSY. – P/L REF.
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
DECIMAL ± .XX= .03
DECIMAL ± .XXX=.005
FRACTIONAL ±
ANGLES ± 1/2°
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
PROJECT
WIRE EDM
TOP 'V' BLOCK
SCALE
FULL
SOURCE DOCUMENT (CREATE/CHG)
W/O 8557
DRAWN
D.S.
DATE
7-13-95
CHECKED
DATE
SHTS.
SHT.
DRAWING NUMBER
B–803–28531
CHANGES

WIRE EDM

chapter 9

MACHINED FEATURES

Machined features are specified on the print with dimensions, notes, and details. This information is interpreted and used to manufacture the part using a machining process. Machining processes are selected based on design requirements, material properties, forming process, machinability of the material, and production efficiency. Machining equipment is designed to efficiently remove material from the shaped part to the required specifications.

MATERIALS

Material specifications are listed in the Bill of Material of the print. The Bill of Material also provides a listing of all materials required to produce the product specified on the print. Information commonly included in the Bill of Material is the item number, quantity, part number or name, material specifications, remarks, and weight. Material specifications may also be listed next to the part. See Figure 9-1. Materials commonly used in the machine trades include metals and plastics.

A *metal* is a material consisting of one or more chemical elements having a crystalline structure, high thermal and electrical conductivity, the ability to be deformed when heated, and high reflectivity. A metal is either pure metal or an alloy. A *pure metal* is a metal that consists of one chemical element. Pure metals are usually soft and have relatively low strength. An *alloy* is a metal that consists of more than one chemical element, with at least one of the elements being a pure metal. Metals are classified as ferrous or nonferrous metals.

Ferrous Metals

A *ferrous metal* is a metal that has iron as the major alloying element. Ferrous metals are magnetic. Pure iron is very soft, extremely ductile, and melts at a low temperature. Iron is commonly alloyed with carbon and other elements to form carbon steel. Carbon steel has a higher tensile strength than pure iron, and is commonly used in fabrication and manufacturing. Carbon steel can be broadly grouped into low-, medium-, and high-carbon steel classifications depending on the percent of carbon steel.

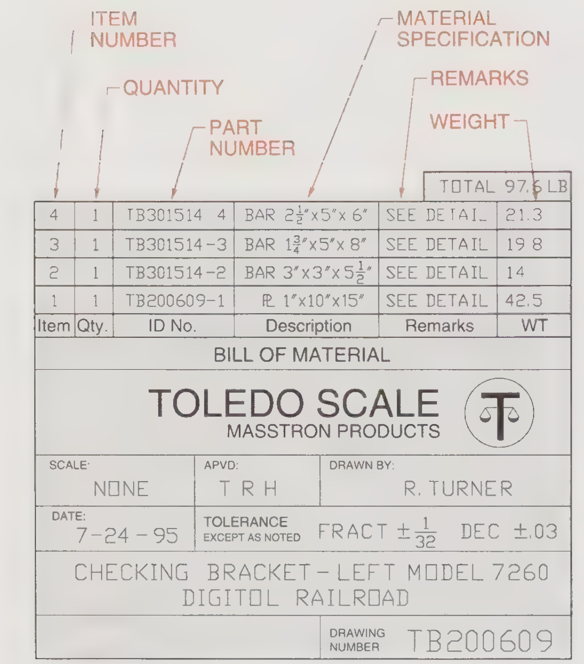


Figure 9-1. The Bill of Material lists specifications of parts included on the print.

Low-carbon steel contains thirty hundreths of a percent (.30%) or less of carbon. Low-carbon steel is the weakest of the carbon steels, and cannot be hardened. It is easily welded and is commonly used for machine parts where soft steel is required. Medium-carbon steel contains approximately .31% to .60% carbon and is stronger than low-carbon steel. Medium-carbon steel can be hardened, and is used where high tensile strength is required on parts such as hammers, wrenches, and screwdrivers. High-carbon steel contains greater than .61% carbon. High-carbon steel can be hardened to obtain high strength for use in cutting tools, machine parts, and drills. The application determines the carbon content of the steel required. See Figure 9-2.

In addition to carbon, other elements such as nickel, chromium, and tungsten can be added to change the properties of the steel. Carbon steels and other alloy steels are classified by the American Iron and Steel Institute (AISI) and the Society of Automotive Engineers (SAE) designation system. The AISI-SAE designation system consists of a four digit classification.

CARBON STEEL	
% C	**APPLICATIONS**
.05 to .12	Chain, stampings, rivets, nails, wire, pipe, welding stock, where very soft plastic steel is needed
.10 to .20	Very soft, tough steel; structural steels, machine parts; for case-hardened machine parts, screws
.20 to .30	Better grade of machine and structural steel; gears, shafting, bars, bases, levers, etc.
.30 to .40	Responds to heat treatment; connecting rods, shafting, crane hooks, machine parts, axles
.40 to .50	Crankshafts, gears, axles, shafts, and heat-treated machine parts
.60 to .70	Low-carbon tool steel, used where a keen edge is not necessary, but where shock strength is wanted; drop hammer dies, set screws, locomotive wheels, screw drivers
.70 to .80	Tough and hard steel; anvil faces, band saws, hammers, wrenches, cable wires, etc.
.80 to .90	Punches for metal, rock drills, shear blades, cold chisels, rivet sets, and many hand tools
.90 to 1.00	Used for hardness and high tensile strength, springs, high tensile wire, knives, axes, dies for all purposes
1.00 to 1.10	Drills, taps, milling cutters, knives, etc.
1.10 to 1.20	Used for all tools where hardness is a prime consideration; for example, ball bearings, cold-cutting dies, drills, wood-working tools, lathe tools, etc.
1.20 to 1.30	Files, reamers, knives, tools for cutting brass and wood
1.25 to 1.40	Used where a keen cutting edge is necessary; razors, saws, instruments, and machine parts where maximum resistance to wear is needed; boring and finishing tools

Figure 9-2. The application determines the amount of carbon required in the steel selected.

The first digit indicates the family to which the steel belongs. For example, number 1 indicates a carbon steel, 2 a nickel steel, and 3 a nickel-chromium steel. The numbers continue depending on the family. The second digit indicates the percentage of the principal alloying element. Usually, the second, third, and fourth digits indicate the carbon content in points (hundredths of a percent). For example, 1045 carbon steel has 45 points, or .45% carbon content. In the case of 2340 nickel steel, there is approximately 3% nickel, and .4% carbon. See Figure 9-3.

AISI-SAE DESIGNATION SYSTEM

Numbers and Digits
Carbon steels
10xx — Plain carbon (1% Mn max)
11xx — Resulfurized
12xx — Resulfurized and rephosphorized
15xx — Plain carbon (1.00% Mn to 1.65% Mn max)
Manganese steels
13xx — 1.75% Mn
Nickel steels
23xx — 3.5% Ni
25xx — 5%
Nickel-chromium steels
31xx — 1.25% Ni; .65% Cr and .80% Cr
. . . chart continues in Appendix . . .

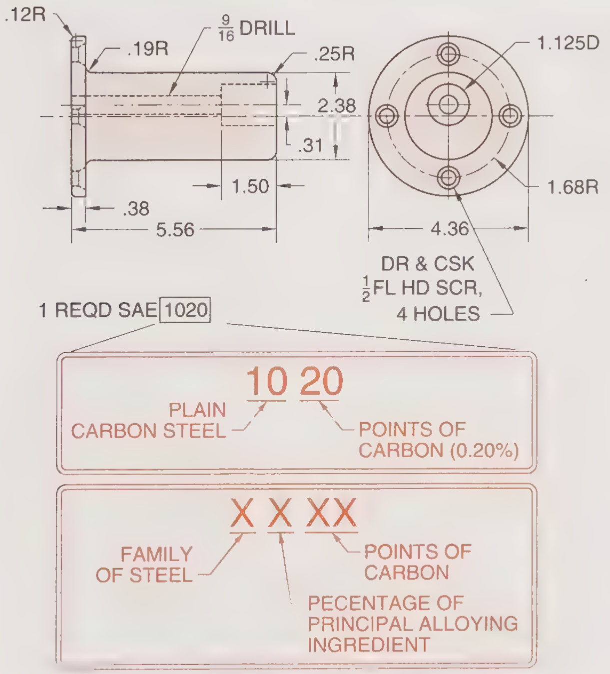


Figure 9-3. The AISI-SAE designation system indicates the alloy content of steels.

The Unified Number System (UNS) was developed through a joint effort of the SAE and the American Society for Testing and Materials (ASTM). The UNS is useful in correlating metals of different designation systems. The UNS uses an uppercase letter followed by 5 numbers. For ferrous metals it consists of D, G, H, or K followed by five numbers. The letter indicates the grouping of steel. The numbers indicate the composition of the metals as indicated by AISI-SAE designations. For example, the AISI-SAE designation of 1045 has a UNS number of G10450. See Appendix.

Steels can also be classified as separate AISI or SAE designations. To qualify for separate AISI designation, the grade of steel must be made in production tonnages. To qualify for separate SAE designation, the grade of steel must meet specific engineering standards and characteristics.

Cast iron is an alloy of iron and carbon containing 1.70% to 4.50% carbon. Cast iron is commonly classified as gray, white, and malleable based on composition and heat treatment. Gray cast iron has a gray colored fracture and is the most common cast iron. It can be easily machined and is widely used for engine blocks, machine tools, and pipe. White cast iron has a silvery-white fracture, and is very hard and brittle. It is used in applications where high resistance to abrasion is desired. Malleable cast iron is white cast iron with additives and or heat treatment to improve strength, ductility, and machinability.

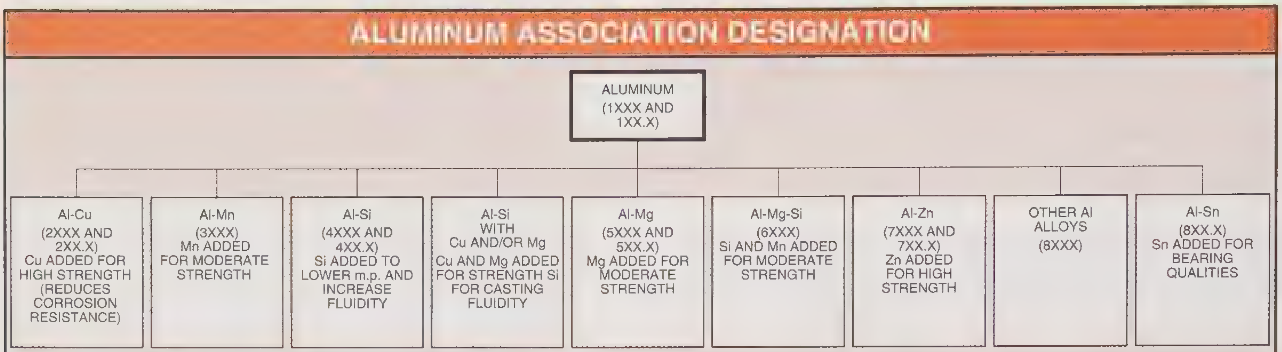
Nonferrous Metals

A *nonferrous metal* is a metal that does not contain iron and is not magnetic. Nonferrous metals are softer than ferrous metals, and have distinctive color differences. Nonferrous metals commonly used in manufacturing include aluminum, copper, brass, bronze, and magnesium. Aluminum is the most commonly used nonferrous metal. It has good machinability, weldability, and resistance to corrosion. Pure aluminum is too soft for most applications and is commonly alloyed with silicon, magnesium, and copper-silicon.

Copper is a heavy, soft metal with high conductivity and corrosion resistance. It is commonly alloyed with zinc to form brass, or with tin to form bronze. Magnesium is a light structural metal with good machinability and strength to weight characteristics. It is commonly used as an alloy with aluminum in castings requiring high strength with

minimum weight. Magnesium alloys are commonly used in the aircraft industry.

Aluminum is classified by the Aluminum Association using a designation system similar to the AISI-SAE designation system. See Figure 9-4. Aluminum and other nonferrous metals can also be classified using the UNS designation system. See Appendix.



TEMPER DESIGNATIONS

DESIGNATION	CONDITION
F	As-fabricated
O	Annealed
H1	Strain hardened only
H2	Strain hardened and partially annealed
H3	Strain hardened and thermally stabilized
W	Solution heat treated
T1	Cooled from an elevated-temperature shaping process, and naturally aged
T2	Cooled from an elevated-temperature shaping process, cold worked, and naturally aged
T3	Solution heat treated, cold worked, and naturally aged
T4	Solution heat treated and naturally aged
T5	Cooled from an elevated-temperature shaping process and artificially aged
T6	Solution heat treated and artificially aged
T7	Solution heat treated and stabilized
T8	Solution heat treated, cold worked, and artificially aged
T9	Solution heat treated, artificially aged, and cold worked
T10	Cooled from an elevated-temperature shaping process, cold worked, and artificially aged

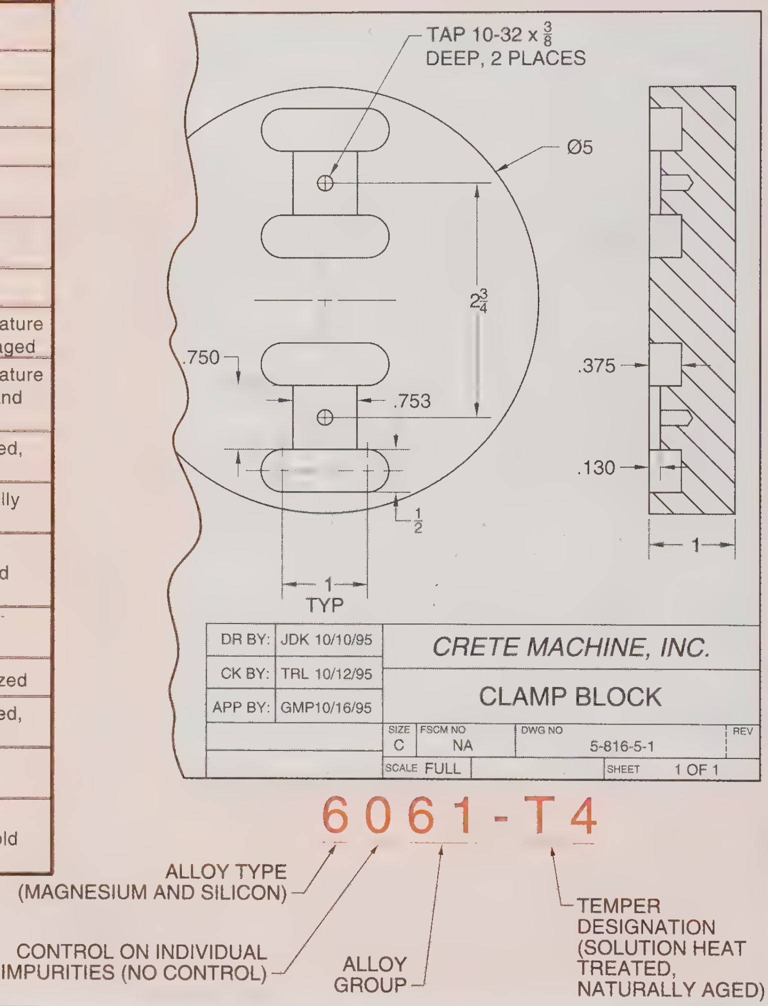


Figure 9-4. Aluminum alloy type, impurities, alloy group, and temper designation are included on the Aluminum Association designation number.

Plastics

Plastics are classified by their principal ingredients (polymers) and can be broadly grouped into thermoplastic and thermosetting plastics. *Thermoplastic plastics* are plastics that will soften repeatedly when heat is applied. Common thermoplastic plastics include acrylics, polystyrenes, polyethylenes, and polyvinyl chlorides.

Thermosetting plastics are plastics that will soften only once when exposed to heat. After heating and shaping into a specific form, thermosetting plastics will not soften with subsequent heat applied. Common thermosetting plastics include epoxies, silicones, and polyesters. The composition of plastics determines machinability and resistance to stretching (tensile strength), and resistance to compression (compressive strength). See Figure 9-5.

MATERIAL PROPERTIES

The characteristics of materials are classified as either mechanical, chemical, or physical properties.

PLASTICS								
POLYMER	CLASSIFICATION		MACHINABILITY				TENSILE STRENGTH*	COMPRESSIVE STRENGTH*
	THERMO-PLASTIC	THERMO-SETTING	POOR	FAIR	GOOD	EXC		
Acetal	✓					✓	8,800	13,000
Acrylic	✓				✓		9,000	16,000
Acrylonitrile Butadiene Styrene	✓				✓		7,000	10,000
Cellulose Acetate	✓					✓	8,000	28,000
Epoxy		✓		✓			17,000	35,000
Ionomer	✓				✓		4,000	8,000
Melamine Formaldehyde		✓		✓			8,300	30,000
Nylon	✓					✓	15,000	13,000
Polycarbonate	✓					✓	9,500	12,500
Polyester		✓			✓		30,000	25,000
Polyethylene, Low Density	✓				✓		2,000	2,300
Polyethylene, High Density	✓					✓	5,000	3,200
Polyphenylene Oxide	✓					✓	9,600	16,000
Polypropylene	✓				✓		5,300	7,000
Polystyrene	✓				✓		7,000	15,000
Polyurethane		✓			✓		6,000	20,000
Polyvinyl Chloride	✓					✓	4,800	11,000
Silicone		✓		✓			28,000	15,000
Tetrafluoroethylene	✓					✓	5,000	1,700

* psi

Figure 9-5. Plastics are classified as thermoplastic and thermosetting plastics and are identified by their principal ingredients.

Mechanical properties are the properties of a material under applied loads. In machining, mechanical properties which have the greatest effect are ductility, hardness, brittleness, toughness, and malleability. See Figure 9-6.

Ductility is the ability of a material to stretch, bend, or twist without breaking or cracking. For example, high ductility metals such as copper deform and fail gradually. Low ductility materials deform only slightly before failure occurs.

Hardness is the ability of a material to resist indentation. *Brittleness* is the lack of ductility in a material. For example, brittle metals will fracture quickly under low stress conditions.

Toughness is a combination of strength and ductility of a material. *Malleability* is the ability of a material to be deformed by compressive forces without developing defects.

Physical properties are the thermal, electrical, optical, magnetic, and general properties of a material. Of the physical properties, thermal properties affect machining operations the greatest. *Thermal expansion* is the expansion of a material when subjected to heat. The amount of thermal expansion is expressed as the coefficient of thermal expansion. The *coefficient of thermal expansion* is the unit change in the length of a material caused by changing the temperature 1°F. See Figure 9-7.

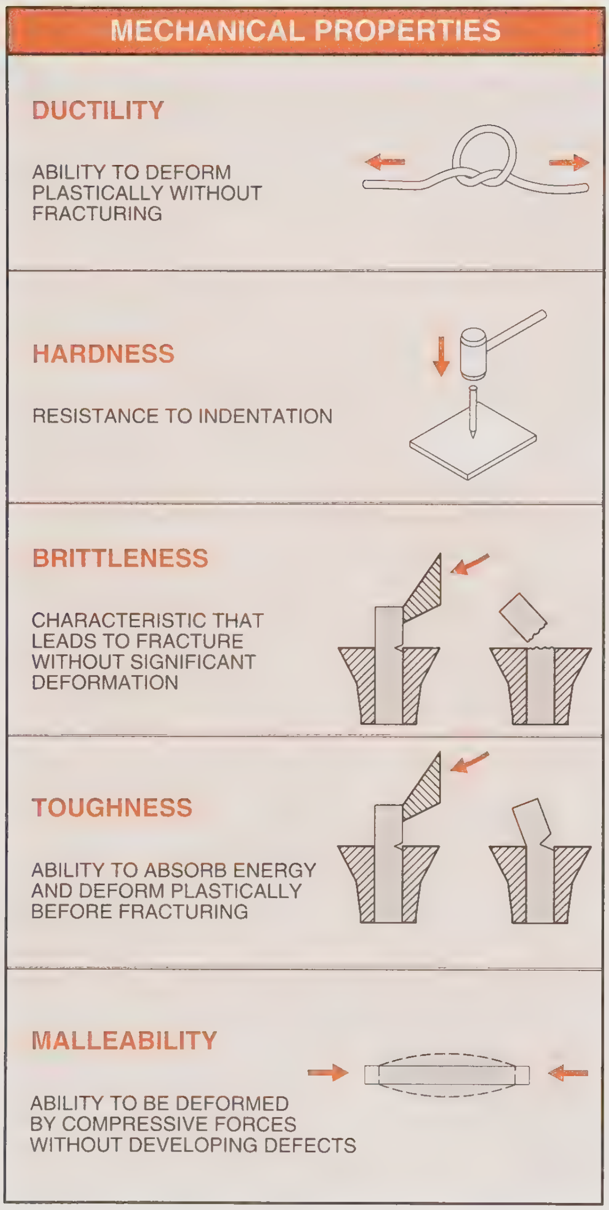


Figure 9-6. Mechanical properties of materials have the greatest effect on the machinability of the part.

COEFFICIENT OF THERMAL EXPANSION

$$C = \frac{L_d}{\Delta T}$$

WHERE
C = coefficient of thermal expansion
L_d = length differential
ΔT = temperature difference in °F

What is the coefficient of thermal expansion of an 8″ wrought iron bar increased to 8.0000661″ when the temperature is increased from 68°F to 78°F?

$$C = \frac{L_d}{\Delta T}$$

$$C = \frac{.0000661}{10}$$

$$C = \mathbf{.00000661''/°F}$$

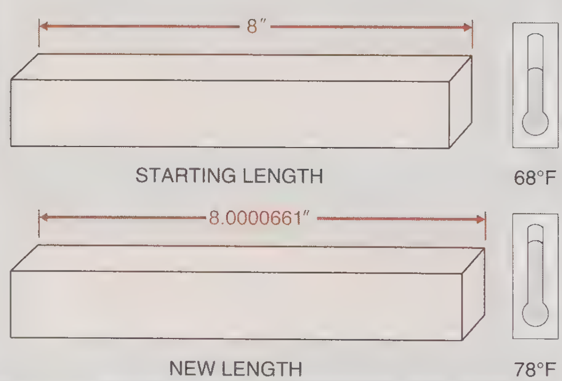


Figure 9-7. The coefficient of thermal expansion is the unit change in the length of a material caused by changing the temperature 1°F.

Thermal expansion occurs in all dimensions of metal when exposed to heat. Different metals have different coefficients of thermal expansion.

Chemical properties are the properties of a material pertaining to chemical reactivity of the material and the surrounding area such as corrosion and oxidation. Chemical properties are the result of the molecular composition of the material.

FORMING PROCESSES

Forming processes shape the part prior to final machining operations. Common forming processes include stamping, casting, bending, forging, rolling, drawing, extruding, and spinning. See Figure 9-8. *Stamping* is the process of applying pressure from two dies to form a part. As pressure is applied, the metal is bent in several directions in one operation. Generally, stamping is used when a uniform thickness is desired throughout the part.

Casting is the process of pouring molten material into a mold to form a part. The shape of the part can be varied greatly to increase or decrease thicknesses in the part. Machined parts formed by casting have the strength of the part maximized by eliminating sharp corners. Rounded corners of intersecting planes also provide easier release from the casting mold and improve the appearance of the part.

On a print, rounds and fillets indicate that machining is not required after casting. Parts to be machined are indicated on the print by square, sharp edges resulting from machining operations. Fillets and rounds shown on intersecting surfaces are indicated by an arc or curve. *Runouts* are lines on the print which indicate the location of the round or fillet at intersecting surfaces. *Rounds* are rounded external corners. *Fillets* are rounded internal corners which occur at inside edges.

Bending is the process in which a material is uniformly stretched around a straight axis. *Forging* is the process of forming a part with pressure or hammering. Forging can be accomplished with or without heat applied to the material. *Rolling* is the process of squeezing the material between two revolving rolls to obtain the desired part thickness. The rolls are closer together than the starting thickness of the material.

Drawing is the process of pulling a material through a die to shape the part to final size and shape. Drawing may require several steps to reach final specifications. *Extruding* is the process of pushing a material through a die to obtain the desired shape. *Spinning* is the process of drawing a material into the specified shape with pressure on the material as it rotates. The material is formed to match the shape of the mandrel.

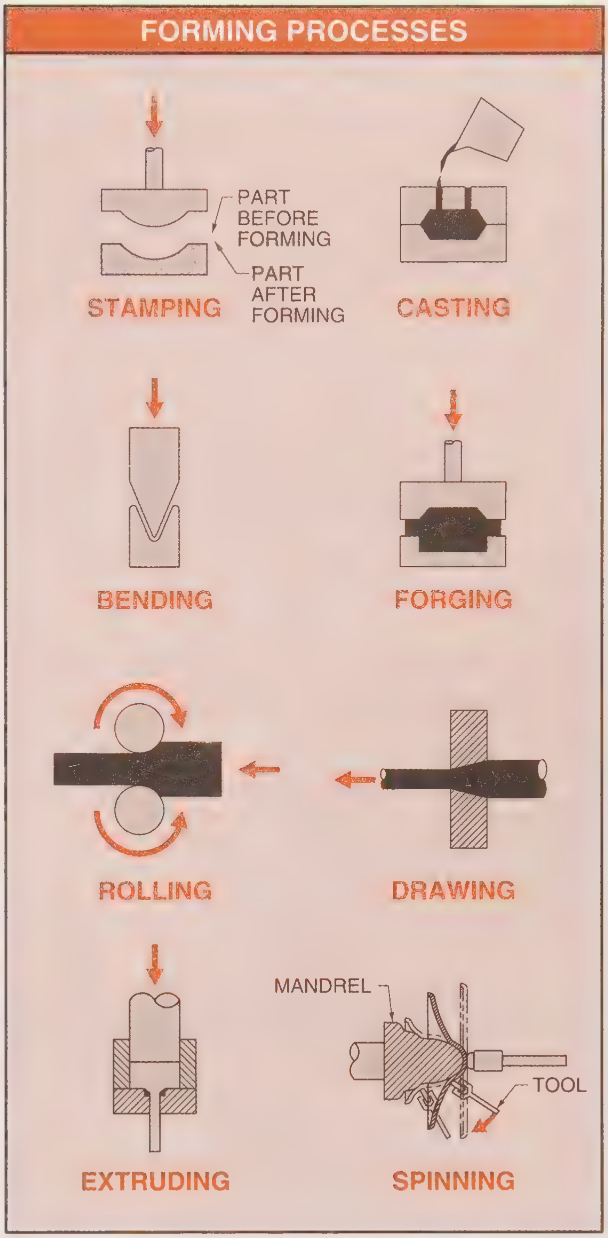
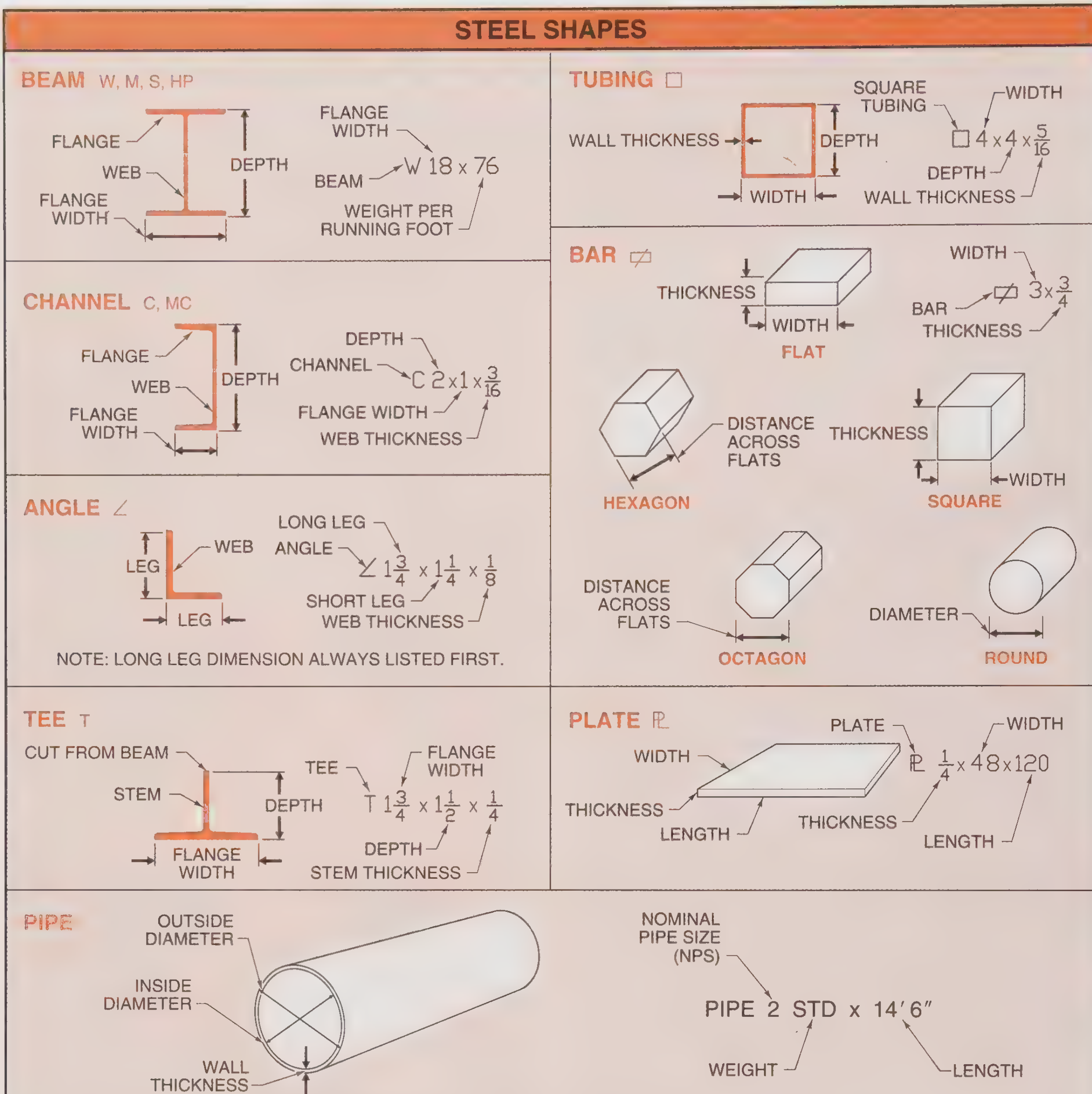


Figure 9-8. Forming processes used to shape the part prior to machining are determined by the mechanical properties of the materials.

Materials are available as standard shapes. For example, standard steel shapes are available in a variety of sizes and configurations. See Figure 9-9. Manufacturers prefer to use standard shapes because of their economy and availability.



NOMINAL INSIDE DIAMETER SIZE (IN.)	OUTSIDE DIAMETER (BW GUAGE)	INSIDE DIAMETER (BW GUAGE)			NOMINAL WALL THICKNESS		
		STANDARD	EXTRA-STRONG	DOUBLE EXTRA-STRONG	SCHEDULE 40	SCHEDULE 60	SCHEDULE 80
1/8	0.405	0.269	0.215		0.068	0.095	
1/4	0.540	0.364	0.302		0 088	0.119	
3/8	0.675	0.493	0.423		0 091	0.126	
1/2	0.840	0.622	0.546	0.252	0.109	0.147	0 294
3/4	1.050	0.824	0.742	0.434	0.113	0.154	0.308
1	1.315	1.049	0.957	0.599	0 133	0.179	0.358
1 1/4	1.660	1.380	1.278	0.896	0.140	0 191	0.382
1 1/2	1.900	1 610	1.500	1 100	0.145	0.200	0.400
2	2.375	2.067	1.939	1.503	0.154	0.218	0.436
2 1/2	2.875	2 469	2 323	1.771	0.203	0.276	0.552
3							

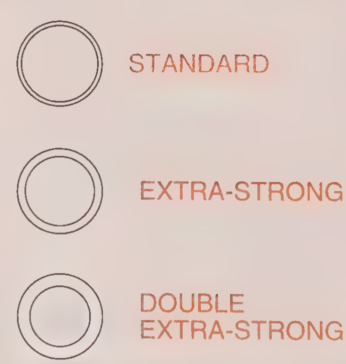


Figure 9-9. Standard steel shapes are used in manufacturing for maximum efficiency and economy.

HEAT TREATMENT

Heat treatment is the application of heat to change the properties of a metal without changing its size and shape. Stresses which build up in the part during the manufacturing process can be removed by annealing. *Annealing* is the process of heating metal and allowing it to cool very slowly. This changes the microstructure to relieve internal stresses, and obtain the desired mechanical and physical properties.

Some parts require additional wear resistance and strength obtained through hardening and tempering. *Hardening* is the process of heating metal followed by quenching in oil, water, or other cooling medium. Hardening the part may require further heat treatment to retain the required mechanical properties. *Tempering* is the process of heating metal followed by controlled cooling at a specific rate. Tempering increases toughness and ductility.

Case hardening is the process of increasing the hardness of a metal surface without changing the mechanical properties of the core. Case hardening is commonly performed by carburizing, induction hardening, or flame hardening. *Carburizing* is a case hardening process in which carbon is introduced into a solid iron-base alloy heated above a certain temperature. Case hardening can also be obtained by induction hardening and flame hardening.

Induction hardening is case hardening a metal surface using electromagnetic induction. Heat in the part is generated by a rapidly alternating field. Electrical resistance of the part causes heat to be generated. Water is commonly used to quench the part as required. *Flame hardening* is the heating of a metal surface with a torch, and quenching to obtain the proper hardness.

MACHINING PROCESSES

Machining is the process of removal of material from the part to the required specifications. The shape and dimensions of the part are specified on the print. The shape and dimensions of the part, and the machinability of the material determine the machining process required.

Machinability

Machinability of a material is the ease or difficulty with which a material can be machined. Machinability of a material is determined by mechanical, physical, and chemical properties. A *machinability rating number* is used to indicate the machinability of a material. See Figure 9-10. Machinability of a material is most affected by the hardness of the material.

MACHINABILITY

SAE NUMBER	AISI NUMBER	TENSILE STRENGTH (psi)	HARDNESS (BRINELL)	MACHINABILITY RATING (percent)
Carbon Steels				
1015	C1015	65 000	137	50
1020	C1020	67 000	137	52
X1020	C1022	69 000	143	62
1025	C1025	70 000	130	58
1030	C1030	75 000	138	60
1035	C1035	88 000	175	60
1040	C1040	93 000	190	60
1045	C1045	99 000	200	55
1095	C1095	100 000	201	45
Free-cutting Steels				
X1113	B1113	83 000	193	120 140
1112	B1112	67 000	140	100
	C1120	69.000	117	80
Manganese Steels				
X1314		71 000	135	94
X1335	A1335	95 000	185	70
Nickel Steels				
2315	A2317	85 000	163	50
2330	A2330	98 000	207	45
2340	A2340	110 000	225	40
2345	A2345	108 000	235	50
Nickel-Chromium Steels				
3120	A3120	75 000	151	50
3130	A3130	100 000	212	45
3140	A3140	96 000	195	57
3150	A3150	104 000	229	50
3250		107 000	217	44
Molybdenum Steels				
4119		91.000	179	60
X4130	A4130	89.000	179	58

SAE NUMBER	AISI NUMBER	TENSILE STRENGTH (psi)	HARDNESS (BRINELL)	MACHINABILITY RATING (percent)
Molybdenum Steels (continued)				
4140	A4140	90 000	187	56
4150	A4150	105 000	220	54
X4340	A4340	115 000	235	58
4615	A4615	82 000	167	58
4640	A4640	100 000	201	69
4815	A4815	105 000	212	55
Chromium Steels				
5120	A5120	73 000	143	50
5140	A5140		174 229	60
52100	E52101	109 000	235	45
Chromium-Vanadium Steels				
6120	A6120		179 - 217	50
6150	A6150	103.000	217	50
Other Alloys and Metals				
Aluminum (11S)		49 000	95	300 2000
Brass Leaded		55 000	RF 100	150 600
Brass Red or Yellow		25 - 35 000	40 55	200
Bronze Lead-bearing		22 - 32 000	30 65	200 500
Cast Iron Hard		45 000	220 240	50
Cast Iron Medium		40 000	193 220	65
Cast Iron Soft		30 000	160 193	80
Cast Steel (0 35 C)		86 000	170 212	70
Copper (F M)		35 000	RF 85	65
Low-Alloy High-Strength Steel		98 000	187	80
Magnesium Alloys				500 2 000
Malleable Iron				
Standard		53 - 60 000	110 - 145	120
Pearlitic		80 000	180 - 200	90
Pearlitic		97 000	227	80
Stainless Steel (12% Cr F M)		120 000	207	70

RATING FOR FREE-CUTTING STEEL

RATINGS LESS THAN 100 ARE EASIER TO MACHINE THAN FREE-CUTTING STEEL

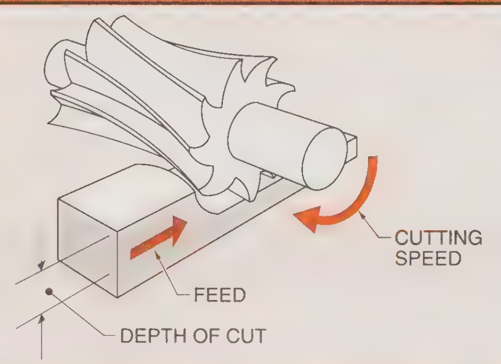
RATINGS GREATER THAN 100 ARE MORE DIFFICULT TO MACHINE THAN FREE-CUTTING STEEL

Figure 9-10. Machinability of a material is indicated by a machinability rating number.

Free-cutting steel, SAE 1112, has a machinability rating of 100%. Machinability rating numbers with less than 100% indicate greater difficulty in machining. Machinability rating numbers with more than 100% indicate greater ease in machining. For example, 1045 carbon steel has a machinability rating of 55%. Compared to 1045 carbon steel, aluminum is very soft and has a lower tensile strength. The machinability rating for aluminum ranges from 300% to 2000% based on the alloy content.

The machinability rating of a material is a factor in the machining operations selected. Machining operations consider depth of cut, cutting speed, and feed. See Figure 9-11. *Depth of cut* is the penetration of the cutting tool for each pass expressed in inches (in.) or millimeters (mm). *Cutting speed* is the speed or motion of the cutting tool in the machining operation. The cutting speed can also indicate the movement of the work or surface speed. Cutting speed is expressed in feet per minute (ft/min) or meters per minute (m/min).

MACHINING OPERATIONS



HIGH-SPEED STEEL CUTTING TOOL

MATERIAL	LATHE		MILLING MACHINE	
	FT/MIN	M/MIN	FT/MIN	M/MIN
Machine steel	90 - 100	27 - 30	70 - 100	21 - 30
Tool steel	70 - 90	21 - 27	60 - 70	18 - 20
Cast iron	60 - 80	18 - 24	50 - 80	15 - 24
Bronze	90 - 100	27 - 30	65 - 120	20 - 25
Aluminum	200 - 300	61 - 93	up to 1,000	up to 300

Figure 9-11. The material machined determines the depth of cut, cutting speed, and feed required.

Feed is the rate at which the cutting tool advances in relation to the cutting tool motion. In drilling, turning, and boring operations, feed is expressed in inches per revolution (IPR) or millimeters per revolution (mmpr). In shaping operations, feed is expressed in inches per stroke (in/st) or millimeters per stroke (mm/st). In milling operations, feed is expressed in inches per tooth (ipt) or millimeters per tooth (mmpt). The machining process selected is based on factors such as cutting speed, depth of cut, cutting tool design, and the cutting tool characteristics. Machining processes commonly used include milling, shaping, turning, grinding, drilling, and boring. See Figure 9-12.

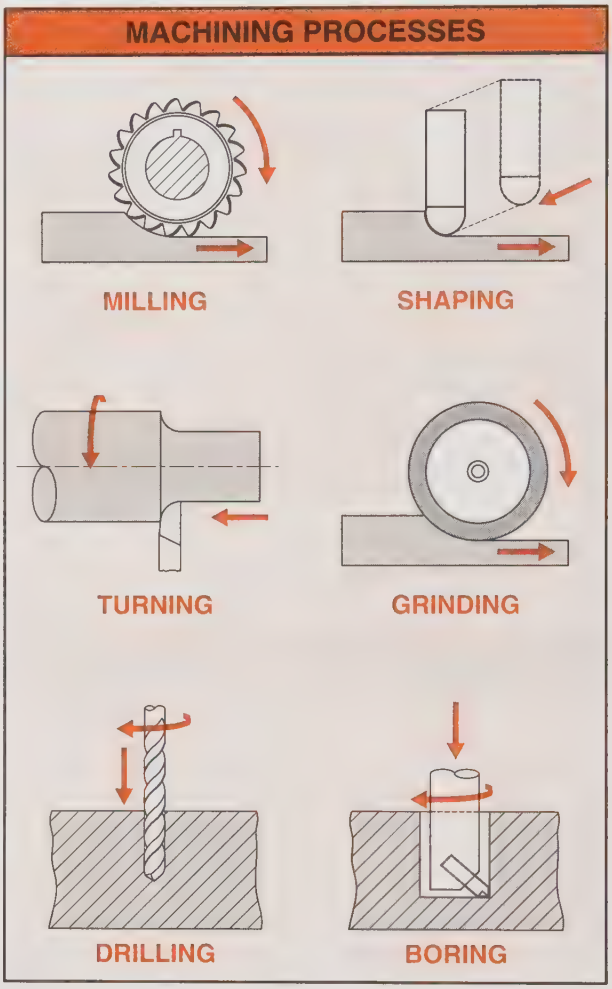


Figure 9-12. Machining processes are selected for part requirements and efficiency.

Milling

Milling combines the rotation of the cutting tool and the feeding of the work into the path of the cutter. The milling machine cutting tool is a circular cutting tool with multiple teeth. Each tooth removes a portion of the work as it rotates on its

axis, and the work is fed into the path of the cutting tool by the movement of the table. The movement of the cutting tool and the work is positioned and controlled by x, y, and z coordinates. The milling machine can be used for a variety of industrial operations including drilling, boring, slotting, machining flat and irregular surfaces, and producing gears.

Milling machines are commonly classified as horizontal or vertical milling machines. On a horizontal milling machine, the cutting tool is mounted on a horizontal arbor or spindle. The arbor or spindle axis is parallel to the table. On a vertical milling machine, the cutting tool is mounted in a spindle that is perpendicular to the table.

Shaping

Shaping is a cutting operation performed by the reciprocating motion of the cutting tool on a shaper. The cutting tool moves back and forth in an axis parallel to the table. The table controls the feeding path of the work into the cutting tool. Shapers are commonly used for machining flat surfaces, external and internal keyseats, and T-slots.

Turning

Turning is a cutting operation performed with the work rotating and the cutting tool fed into or away from the work. Turning operations are commonly performed on a lathe. The lathe is one of the most versatile machine tools. In addition to producing cylindrical parts, the lathe is used for producing threads, tapers, and other machined features.

The cutting tool is mounted in a tool rest fastened to the compound rest. The compound rest can be rotated on the cross slide to position the cutting tool at various angles to the work. The cross slide moves the cutting tool in and out at 90° to the axis of the work.

The compound rest and cross slide are mounted on the carriage which allows the cutting tool to be traversed parallel to the axis of the work as required. Cutting tools on the lathe are designed for obtaining the desired cut and finish. Different cutting tools and cutting operations require specific speeds and feeds.

Grinding

Grinding is the process of removing material using an abrasive wheel mounted on a rotating horizontal or vertical arbor. The work is fed into the path of the grinding wheel. The abrasive grains in the grinding wheel act as miniature cutting tools to remove a controlled amount of material.

Grinding wheels are classified according to abrasive material, grain size, and type of bond used to join the grains. The grinding wheel required is determined by the material properties and the surface finish desired.

Common abrasive materials include aluminum oxide, silicon carbide, and diamonds. Grain size is determined by the grit number. For example, an 80 grit grinding disc has abrasives that will not fall through a 1″ × 1″ screen with more than 80 openings.

A grinding symbol similar to a square root sign specifies the grinding grit. The symbol is placed on the edge of the surface to be ground. See Figure 9-13.

Grinding can be performed with very light pressure, and can remove material to close tolerances. Grinding operations can be used to obtain size, and produce the desired surface characteristics. The operation determines the type of grinding wheel required.

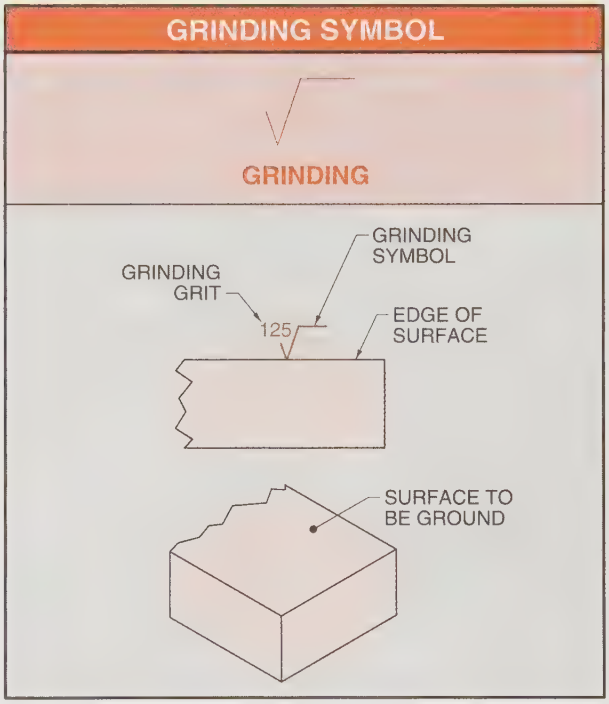


Figure 9-13. The grinding symbol is placed on the edge of the surface to be ground.

Drilling

Drilling is the cutting of round holes in material with a drill. See Figure 9-14. Holes are made or enlarged using rotary motion of the drill, or rotary motion of the work, or both. The drill, the work, or both are held in a spindle, and rotate in the drilling process. A drill press, lathe, or milling machine may be used for the drilling process. See Appendix. Symbols are used on prints to show the specific drilling operation. Drill symbols include counterbore or spotface, countersink, and depth. A size note accompanies the drill symbol. See ANSI Y14.5M.

Drills are available in fractional, number, and letter sizes. See Appendix. Fractional drills have diameters of 1⁄64″ to 1¾″ in 1⁄64″ increments, 1¾″ to 2¼″ in 1⁄32″ increments, and 2¼″ to 3½″ in 1⁄16″ increments.

Number drills are available in sizes from No. 1 through No. 80. A No. 1 drill is .2280″ in diameter. A No. 80 drill is .0135″ in diameter. The larger the number, the larger the drill.

Letter drills are available in sizes A through Z. An A drill is .234″ in diameter. A Z drill is .413″ in diameter. Letters near the beginning of the alphabet represent smaller drill sizes.

Jobber length drills are used for general purpose drilling. Taper length drills are used for general

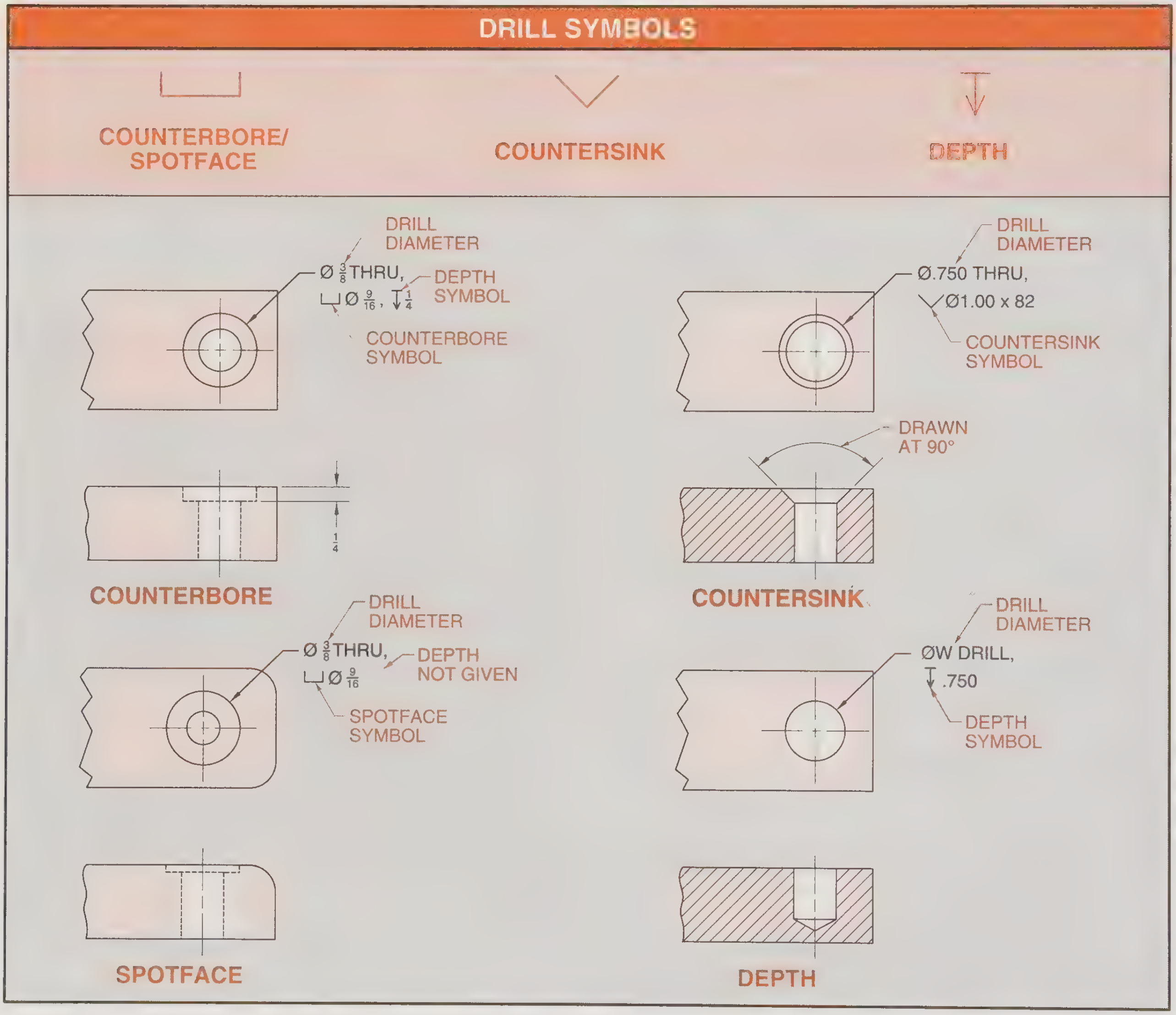


Figure 9-14. Symbols are used on prints to show drilling operations.

purpose drilling where a longer length is required. Screw machine length drills are used for thin metals where a shorter length is required.

Drills may have round, hex, or tapered shafts. They have a variety of point designs based upon their application.

Boring

Boring is the process of enlarging an existing hole or shape to specifications with a cutting tool. The purpose of the boring operation is to enlarge holes to specified tolerances, clean a drilled hole, or to remove eccentricity of the hole.

Boring is most commonly performed using a single point cutting tool. Boring can also be performed with a multiple edge tool. Boring can be performed on a drill press, lathe, or vertical or horizontal milling machine. *Reaming* is a boring operation which enlarges a hole to improve the surface quality of a hole.

GROOVES

Grooves are machined internal or external sections of a part. Grooves can be used to provide relief when cutting threads or when performing knurling operations. See Figure 9-15. Grooves are classified as square grooves, V-grooves, or round grooves. Square grooves are cut into work and have shoulders that are 90° to the axis of the work. This provides a bearing surface for seats of mating parts. Square grooves are also used with retaining rings and clips.

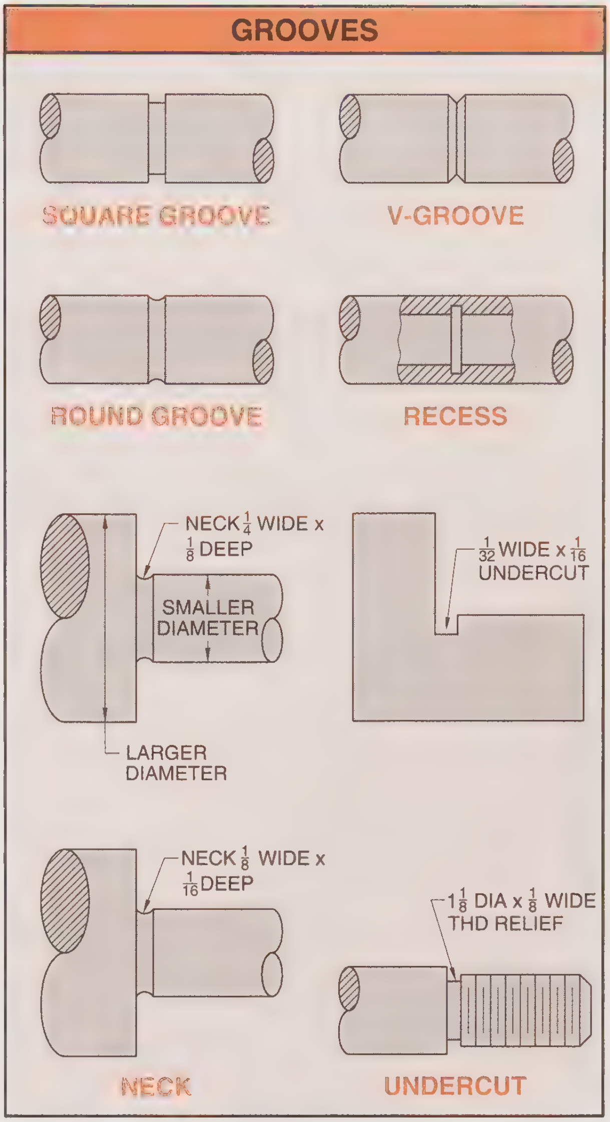


Figure 9-15. Grooves are machined below the surface of the material to provide clearance and bearing surfaces.

V-grooves are cut into the work and have shoulders that are at an angle. The angled surface is commonly used as a bearing surface for drive belts. The angled surface can also be used as a finished surface before cutting the completed part to final size.

Round grooves have shoulders that provide greater strength than square grooves. Round grooves are commonly used for seating springs, washers, and seals. A *recess* is a groove cut into the internal diameter of a cylinder. A recess can be used for the same functions as other groove types.

A *neck* is a recess cut into a cylindrical part to provide a space between where one diameter changes to another diameter on a cylinder. The neck assures that a pulley installed on the shaft would fit in full contact against the shoulder of the larger diameter.

An *undercut* is a recessed area machined at the intersection of two perpendicular planes. Like a neck, the undercut provides clearance to allow mating parts to fit in full contact with one another. An undercut can also be used to provide clearance for threads cut into a smaller diameter adjacent to a larger diameter.

Grooves are commonly produced using a milling machine, shaper, or lathe. In some instances, grooves can be produced with a grinding operation.

SLOTS

Slots are elongated holes or rectangles machined into the part. Slots are produced with a milling machine or a shaper. Slots are specified by dimensions between centerpoints and radius dimensions. A centerpoint can be used to indicate the slot size and location. See Figure 9-16.

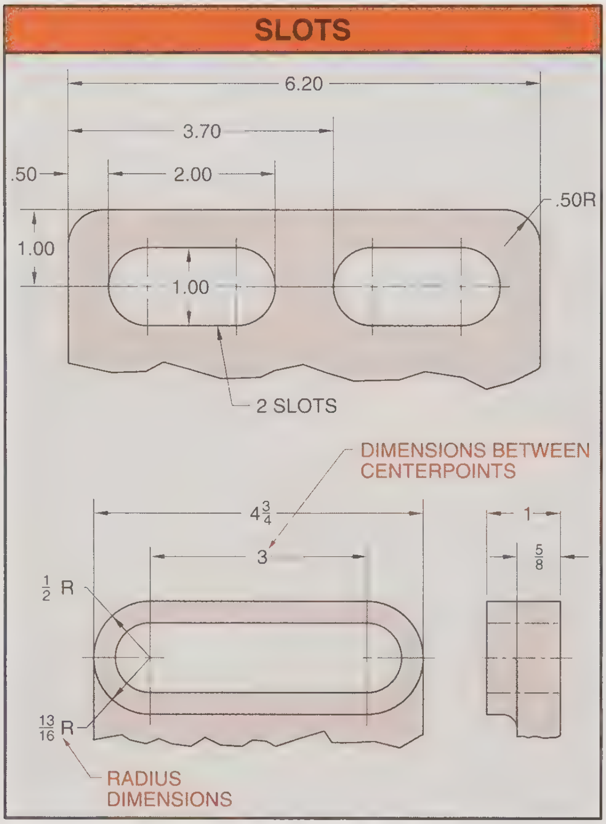


Figure 9-16. Slots are commonly machined to specifications using a milling machine.

KEYSEATS

A *keyseat* is a machined rectangular groove along the axis of a shaft or hub that mates with a key. *Keys* are removable parts which provide a positive means of transmitting torque between a shaft and hub when mounted in a keyseat. This maintains consistent rotation speed between a shaft and attached parts such as pulleys, cranks, or wheels.

The keyseat specified is based on the strength requirements and the key selected. Keys commonly used include the parallel, taper, and Woodruff. Dimensions for keys are standardized to fit in specific dimensions.

Keyseats on a shaft are dimensioned by the thickness and radius of the mating key, and the distance from the opposite side of the shaft or hole. Keyseats on a hub are dimensioned by the thickness, depth, and length. The distance from the opposite side of the shaft or hole is also given. Keyseats are commonly machined into the part using the milling process. See Figure 9-17.

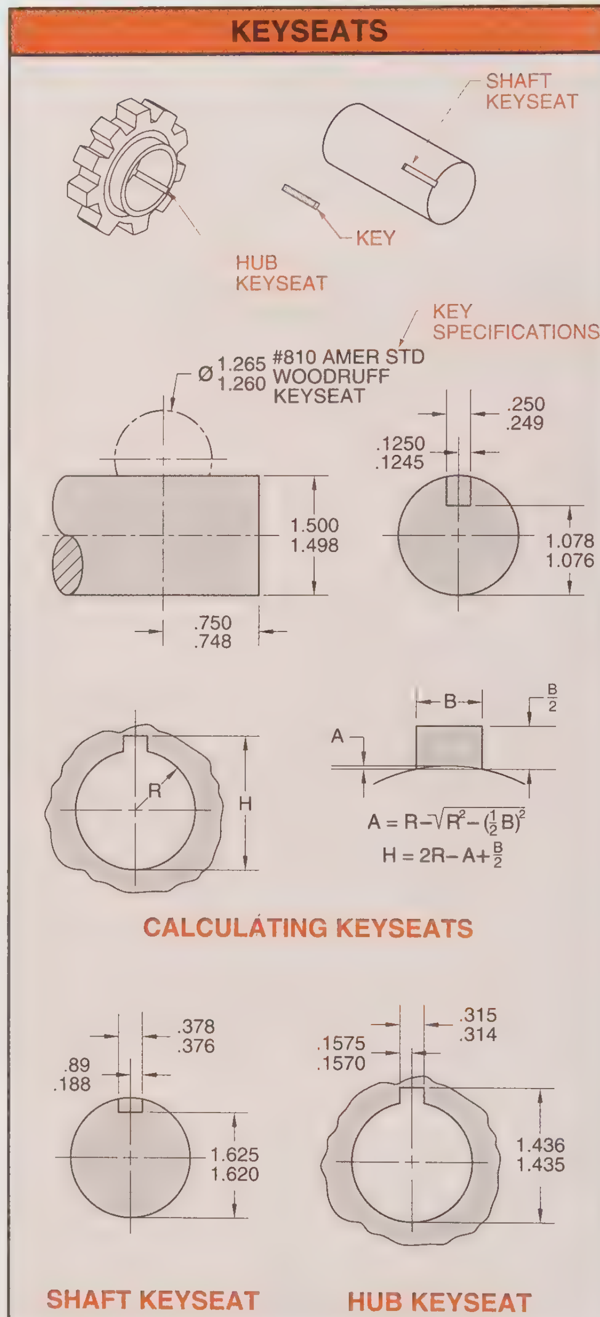


Figure 9-17. Keyseats are grooves machined into a shaft or hub which match key specifications.

SPOTFACES

A *spotface* is the machined flat surface at a right angle to the drilled hole. A spotface can be used on recessed or raised surfaces of the part to provide a bearing surface for a mating part. On a recessed surface, spotfacing is a counterboring operation. On a raised surface, spotfacing is used to finish a boss on the part.

A *boss* is a short projection with a finished surface which extends above the surface of a part. The top surface of the projection is machined to remove any surface irregularities, and to match the bearing surface of a mating part. A boss increases the strength in load bearing areas of the casting. Spotfaces are produced using the drilling or milling process. See Figure 9-18.

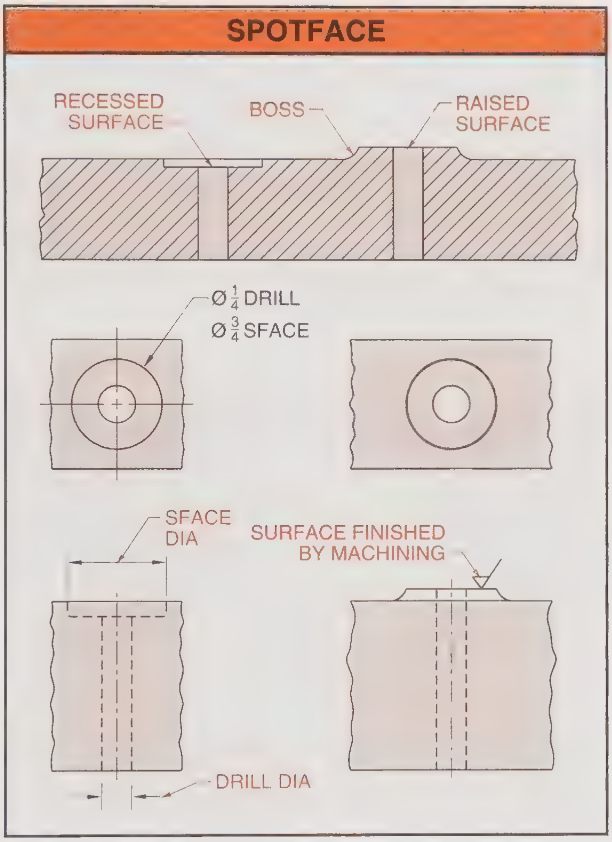


Figure 9-18. Spotfaces provide a level bearing surface for load transfer.

TAPERS

A *taper* is a solid or hollow cylinder in which the diameter increases or decreases uniformly from one end to the other. Tapers are specified as determined by the accuracy required. For noncritical applications, the taper may be specified by the large diameter and the small diameter, and the length of the axis of the taper using the necessary tolerances. Taper can also be specified using the included angle desired.

For greater accuracy, the amount of taper per linear unit on the diameter is specified. For example, tapers can be specified as taper per inch, or taper per foot. Taper per inch is equal to the difference between the diameters, divided by the length of the taper in inches. Taper per foot uses 1′ as the linear unit. Tapers are produced by turning or grinding operations, or both. See Figure 9-19.

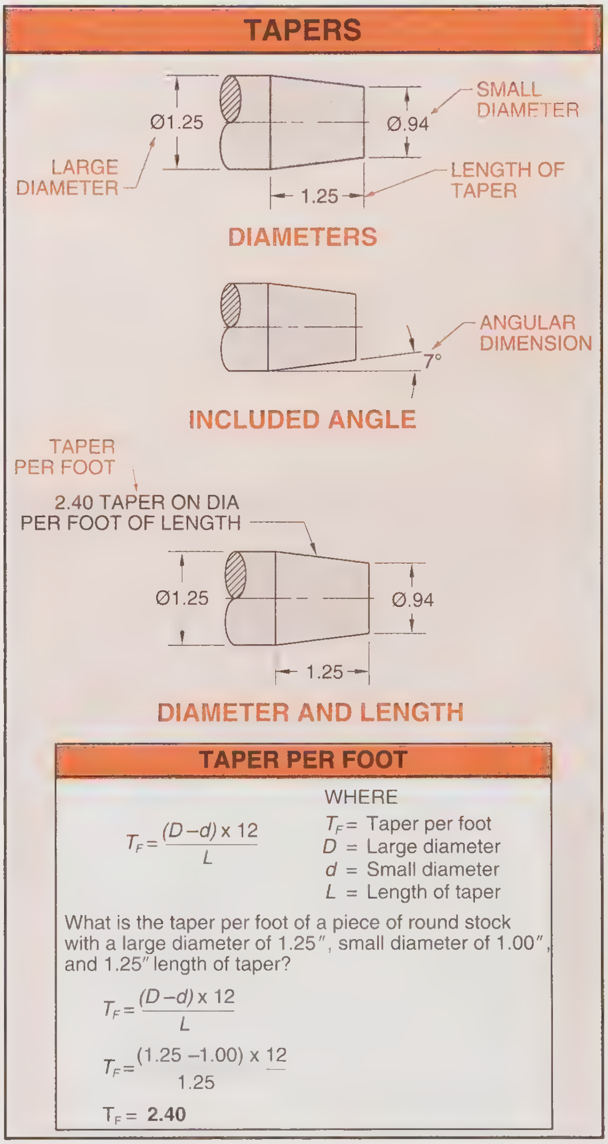


Figure 9-19. Tapers are specified on the print using diameter, included angle, and length specifications.

Standard tapers used in industry include the Morse taper, Brown and Sharpe taper, American National Standard taper, and Jarno taper. Standard tapers are commonly specified for the shank of twist drills, end mills, and lathe centers. Standard tapers are also commonly specified for tapered holes used on drill, milling machine, and lathe spindles.

CHAMFERS

A *chamfer* is a sloped edge of an object running from surface to side. Chamfers are specified on the print by angle and linear dimension, or by two linear dimensions. Chamfers are commonly produced using a milling machine for square shapes, and a lathe for cylindrical shapes. Chamfers can be external or internal. See Figure 9-20.

KNURLS

A *knurl* is a raised pattern formed in a material. A smooth surface of a part is changed into uniform ridges and projections raised above the surface. Knurls are used to produce an embossed surface for the purpose of providing a better grip than a smooth surface. The knurl pattern is formed with pressure from the rolls of a knurling tool on a lathe. The knurling tool rolls have straight or diagonal teeth.

The rolls on the knurling tool provide uniform, localized pressure. The rolls remain in contact with the work until the knurling operation is complete. Common knurl patterns include straight and diamond. Straight tooth patterns are commonly used for fastener heads. The diamond patterns are most commonly used for grips on handles. The diamond pattern is formed by two passes of rolls having diagonal teeth.

Knurls are specified by type, diametral pitch (DP), and length of the knurled area. *Diametral pitch* is the quotient of the total number of teeth in the circumference of the work divided by the work diameter prior to knurling. Surfaces with noncritical dimensions such as a gripping surface may not require diameter dimensions. Critical dimensions, such as a part to be press fit, require diameters specified for before and after the knurling operation. See Figure 9-21.

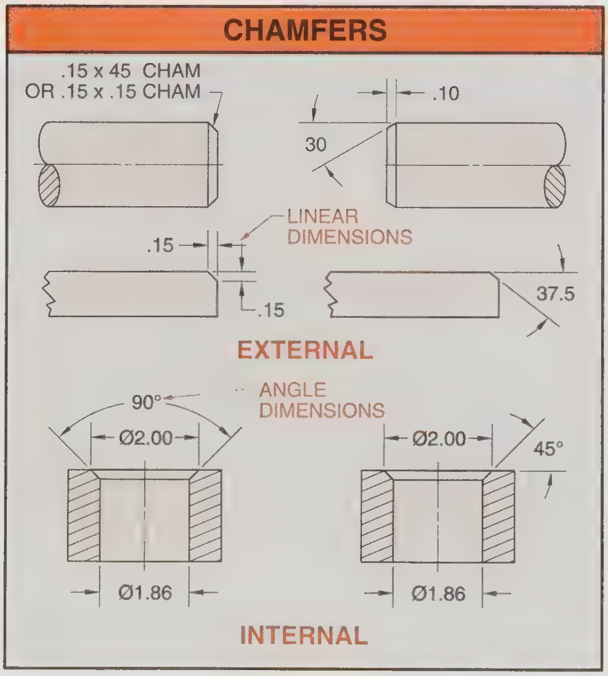


Figure 9-20. Chamfers are specified with angle and linear dimensions.

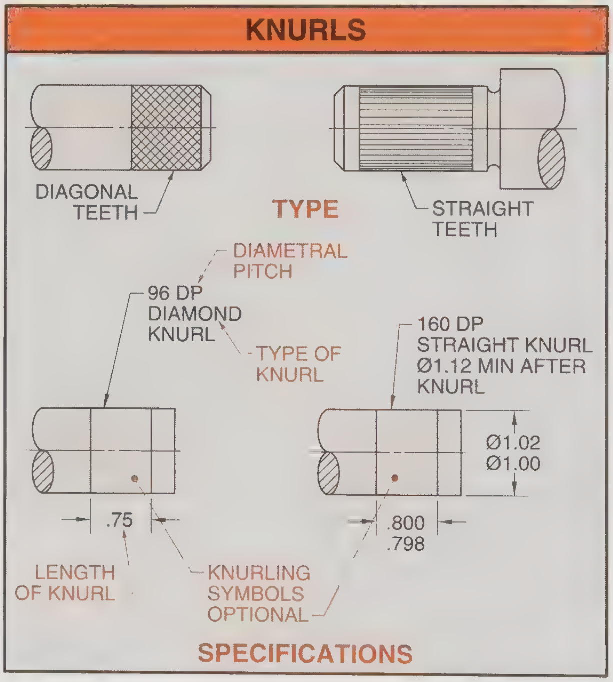


Figure 9-21. Knurls are specified by type, diametral pitch, and length of knurled area.

Review Questions

Name_______________________________________ Date ____________________

Completion

__________ 1. _________-carbon steel is used for cutting tools and drills.

__________ 2. Two dies are used when using the _________ process to form metal.

__________ 3. _________ are rounded internal corners.

__________ 4. Hardening is the process of heating the metal and _________ in oil or water.

__________ 5. A(n) _________ is used to indicate the machinability of a material.

__________ 6. A(n) _________ is an embossed surface that provides a gripping surface on a part.

__________ 7. A key mates with a(n) _________ to prevent slippage between a shaft and hub.

__________ 8. The _________ of thermal expansion is the unit change in length caused by changing the temperature 1°F.

__________ 9. A(n) _________ is a short projection with a finished surface that extends above the surface of the part.

__________ 10. An abrasive wheel is used to remove material in the _________ process.

True-False

T F 1. Shaping is a cutting operation that uses a circular motion of the cutting tool.

T F 2. Turning operations are commonly performed on a lathe.

T F 3. Feed is the rate at which the cutting tool advances in relation to the cutting tool motion.

T F 4. Runouts on a print indicate the diameter of a hole.

T F 5. Carburizing is a case hardening process.

T F 6. Thermosetting plastics soften only once when exposed to heat.

T F 7. Physical properties are the thermal, electrical, and chemical properties of a material.

T F 8. Forging is the process of forming a part using pressure or hammering.

T F 9. A chamfer is a sloped edge of an object running from surface to side.

T F 10. Tapers can be specified using two diameters and the length of the axis of the taper.

Matching — Mechanical Properties

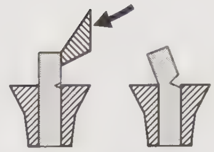
______ 1. Ductility

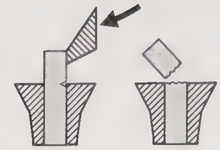
______ 2. Hardness

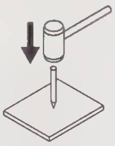
______ 3. Brittleness

______ 4. Toughness

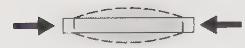
______ 5. Malleability


(A)


(B)


(C)


(D)


(E)

Matching — Machined Features

______ 1. Square groove

______ 2. Slot

______ 3. Undercut

______ 4. Keyseat

______ 5. Taper

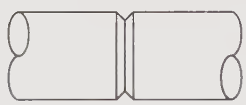
______ 6. Chamfer

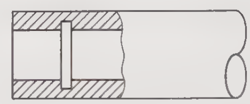
______ 7. Spotface

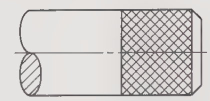
______ 8. Knurl

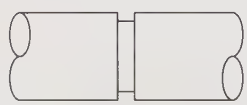
______ 9. V-groove

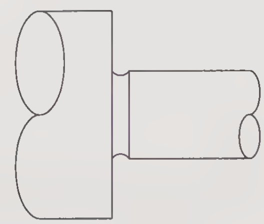
______ 10. Recess

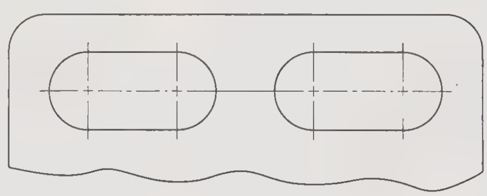

(A)

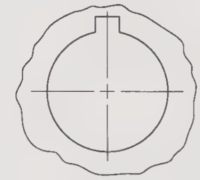

(B)

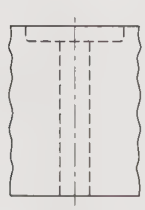

(C)

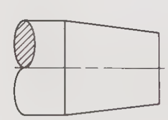

(D)

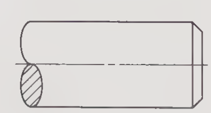

(E)


(F)


(G)


(H)


(I)


(J)

Matching — Machining Processes

__________ 1. Grinding

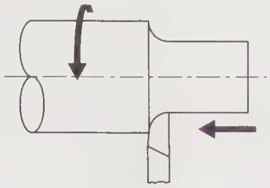
__________ 2. Boring

__________ 3. Turning

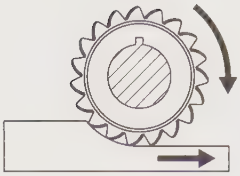
__________ 4. Milling

__________ 5. Shaping

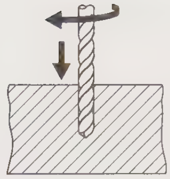
__________ 6. Drilling



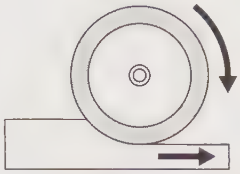
(A)



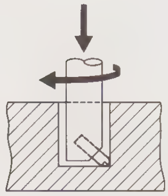
(B)



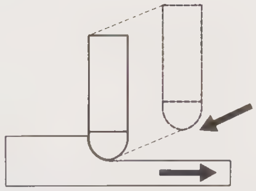
(C)



(D)



(E)



(F)

Matching — Forming Processes

__________ 1. Bending

__________ 2. Forging

__________ 3. Rolling

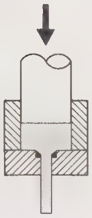
__________ 4. Casting

__________ 5. Stamping

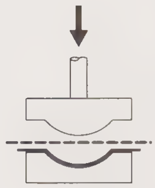
__________ 6. Spinning

__________ 7. Extruding

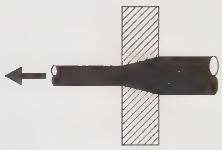
__________ 8. Drawing



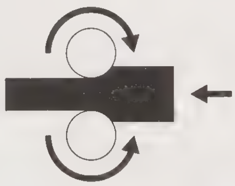
(A)



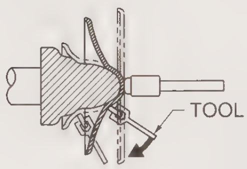
(B)



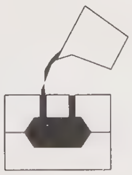
(C)



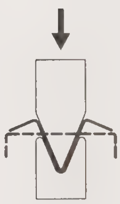
(D)



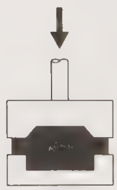
(E)



(F)



(G)



(H)

Multiple Choice

_______ 1. A ferrous metal contains _________.

A. aluminum
B. lead
C. copper
D. iron

_______ 2. The properties of a material under applied load are _________ properties.

A. chemical
B. physical
C. mechanical
D. thermal

_______ 3. _________ is the process of pouring molten material into a mold.

A. Bending
B. Forging
C. Rolling
D. Casting

_______ 4. Internal stresses of a material are relieved through the process of _________.

A. tempering
B. hardening
C. annealing
D. carburizing

_______ 5. A(n) _________ is a rectangular hole machined into the part.

A. neck
B. undercut
C. keyseat
D. slot

_______ 6. Cast iron is an alloy of iron and _________.

A. aluminum
B. carbon
C. chromium
D. zinc

_______ 7. _________ plastics soften repeatedly when heat is applied.

A. Thermoplastic
B. Thermoset
C. Malleable
D. Carburized

_______ 8. Corrosion is a _________ property of a material.

A. mechanical
B. thermal
C. physical
D. chemical

_______ 9. _________ is the ability of a material to stretch, bend, or twist without breaking or cracking.

A. Ductility
B. Toughnes
C. Malleability
D. Strength

_______ 10. _________ is a boring operation used to improve the surface quality of the hole.

A. Reaming
B. Knurling
C. Tapping
D. Spotfacing

◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Armature Shaft *(See page 195.)*

_________ **1.** The maximum diameter of the Armature Shaft is _________.

_________ **2.** The knurled section of the Armature Shaft is _________″.

_________ **3.** All chamfers are specified for a(n) _________° angle.

_________ **4.** The total length of the Armature Shaft is _________″.

_________ **5.** The minimum diameter of the Armature Shaft at the small end is _________″.

_________ **6.** Chamfers are specified for _________″ from the ends of the shaft.

_________ **7.** The distance from the knurl to the small end is _________″.

_________ **8.** The maximum diameter of the knurl is _________″.

T F **9.** Both ends of the Armature Shaft must be drilled.

T F **10.** Note A4 specifies material requirements.

T F **11.** Chamfers specified for the ends have been increased since the original drawing was made.

T F **12.** The minimum diameter of the Armature Shaft is .5000″.

_________ **13.** A(n) _________ tooth knurl pattern is specified on the print.

_________ **14.** The knurl is specified for _________ TPI.

_________ **15.** The distance from the large end to the knurl is _________″.

_________ **16.** The Armature Shaft is drawing number _________.

T F **17.** The Armature Shaft requires heat treatment.

_________ **18.** The drawing was drawn to _________ scale.

_________ **19.** The gear specified requires a(n) _________″ full tooth.

_________ **20.** The minimum diameter for the knurl is _________″.

Center-Die *(See page 196.)*

__________ **1.** Dimension E is ________″.

__________ **2.** Radius K specifies a depth of ________″.

__________ **3.** Chamfer I specifies a(n) ________° angle.

__________ **4.** The maximum diameter of the Center-Die is ________″.

__________ **5.** Radius K specifies a(n) ________″ radius.

__________ **6.** The symbol at G specifies ________.

__________ **7.** The datum located at ________ is used to specify the diameter of the Center-Die.

__________ **8.** Radius M is ________″.

__________ **9.** The minimum diameter of F is ________″.

__________ **10.** Datum A must be ________ to datum B.

__________ **11.** The dimension at D specifies a(n) ________ of .0005″.

__________ **12.** Letter ________ is located at the centerpoint for radius M.

__________ **13.** The depth of chamfer I is ________″.

__________ **14.** The symbol at H specifies ________.

T F **15.** Datum B is used to specify the length of the Center-Die.

T F **16.** The small hole diameter is .802″.

T F **17.** The angle specified at L is 31°.

T F **18.** The depth of the small hole is .753″.

__________ **19.** The symbol at A specifies ________.

__________ **20.** Roughness height is specified for ________ microinches unless specified otherwise.

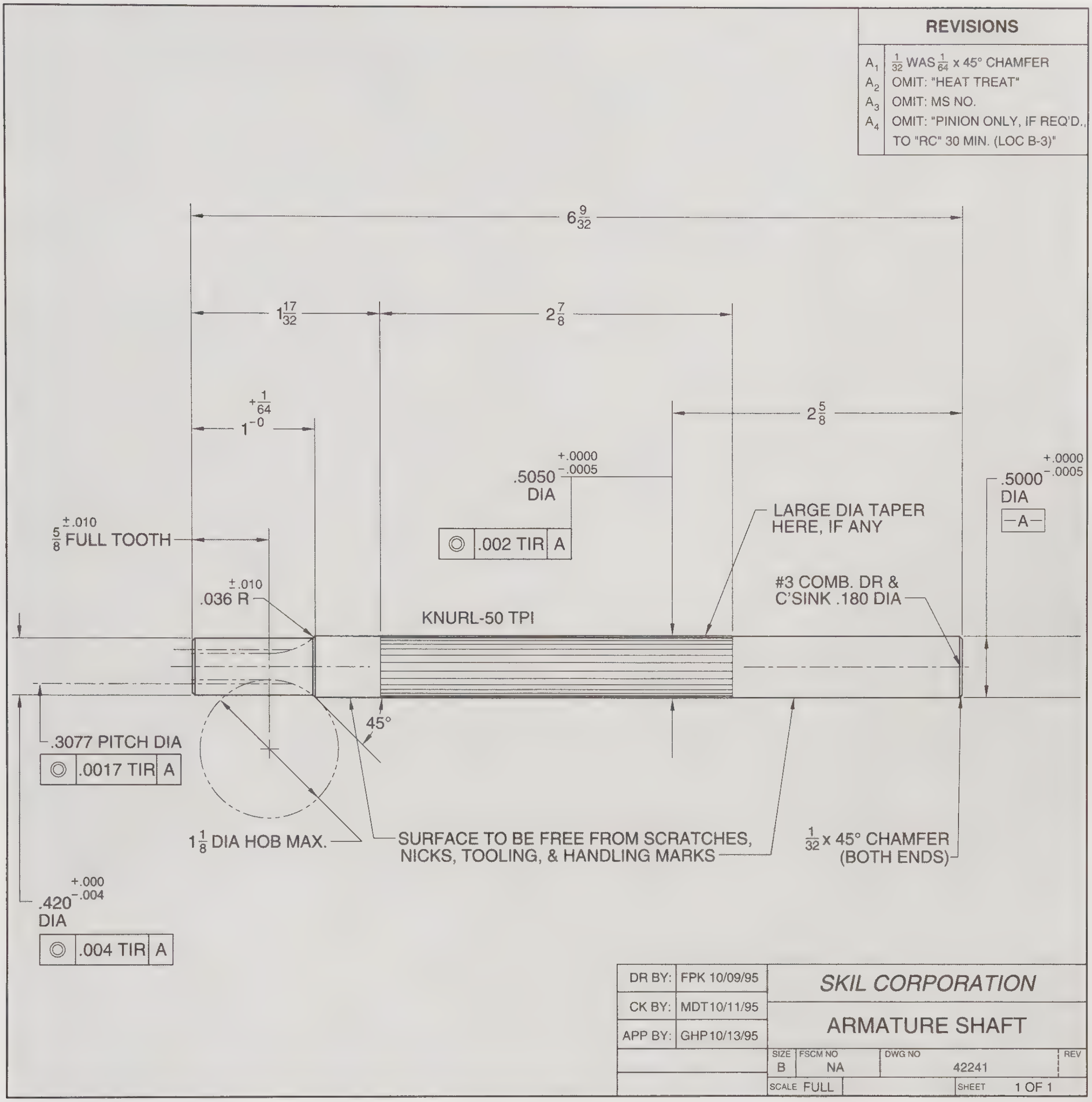
T F **21.** The symbol at B specifies a datum surface.

T F **22.** The surface of the large hole is finished to a roughness of 32 microinches.

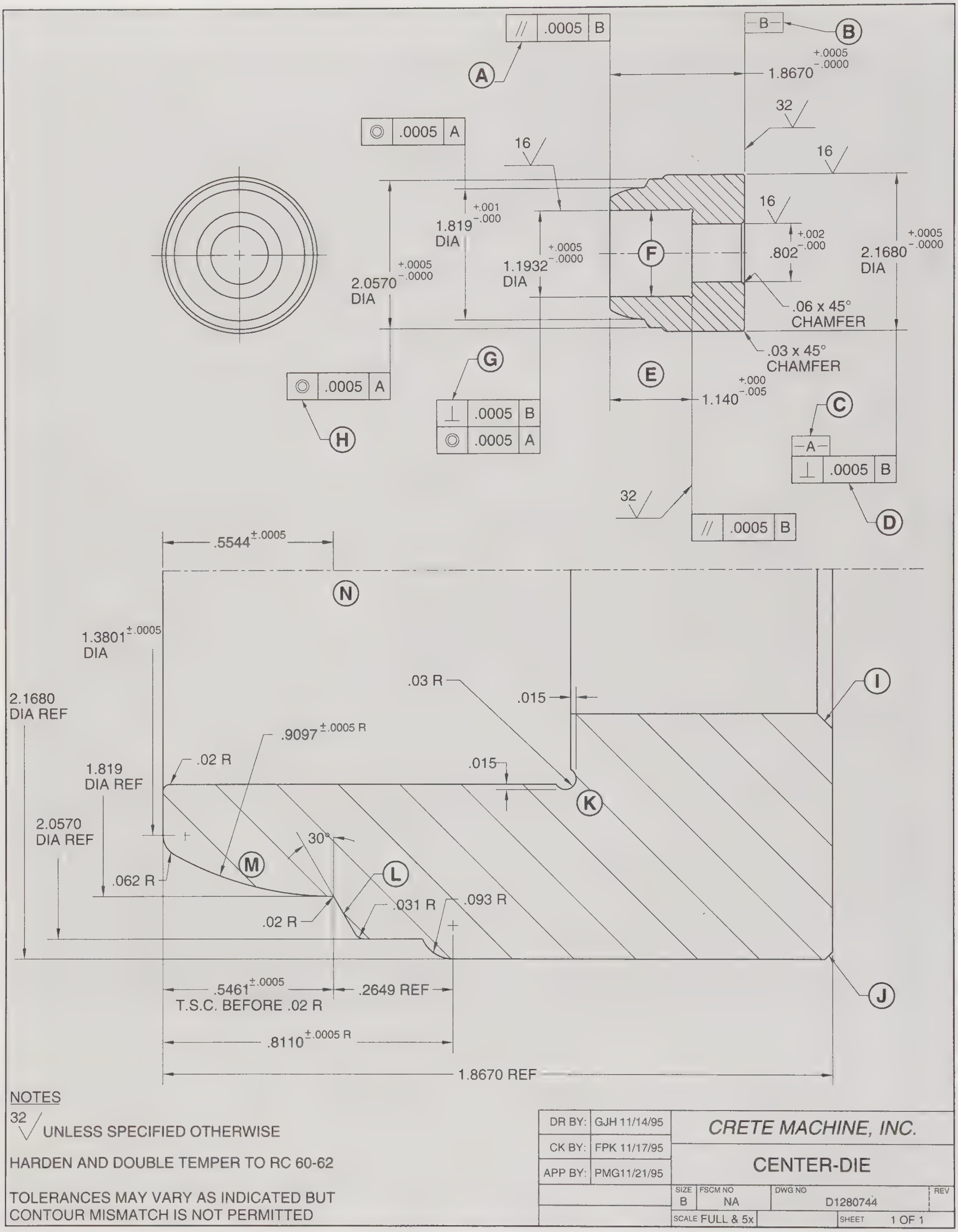
__________ **23.** Chamfer J has a specified dimension of ________.

__________ **24.** The drawing was checked on ________.

__________ **25.** The Center-Die is hardened to ________.



ARMATURE SHAFT


// .0005 B
A
B
+.0005
-.0000
1.8670
32
◎ .0005 A
16
16
+.001
-.000
1.819
DIA
16
+.0005
-.0000
1.1932
DIA
F
+.002
-.000
.802
+.0005
-.0000
2.1680
DIA
+.0005
-.0000
2.0570
DIA
.06 x 45°
CHAMFER
.03 x 45°
CHAMFER
G
E
+.000
-.005
1.140
◎ .0005 A
H
⊥ .0005 B
◎ .0005 A
C
A
⊥ .0005 B
D
32
// .0005 B
.5544 ±.0005
N
1.3801 ±.0005
DIA
I
2.1680
DIA REF
.03 R
.015
.9097 ±.0005 R
.02 R
.015
1.819
DIA REF
K
2.0570
DIA REF
30°
M
L
.062 R
.031 R
.093 R
.02 R
J
.5461 ±.0005
T.S.C. BEFORE .02 R
.2649 REF
.8110 ±.0005 R
1.8670 REF
NOTES
32 UNLESS SPECIFIED OTHERWISE
HARDEN AND DOUBLE TEMPER TO RC 60-62
TOLERANCES MAY VARY AS INDICATED BUT
CONTOUR MISMATCH IS NOT PERMITTED
DR BY: GJH 11/14/95
CK BY: FPK 11/17/95
APP BY: PMG11/21/95
CRETE MACHINE, INC.
CENTER-DIE
SIZE B
FSCM NO NA
DWG NO D1280744
REV
SCALE FULL & 5x
SHEET 1 OF 1

CENTER-DIE

chapter 10

GEARS AND CAMS

Gears are toothed wheels used in pairs to transmit power or motion from one shaft to another. The American Gear Manufacturers Association (AGMA) provides specifications and tolerances for gear applications and their manufacture. Cams are used with cam followers to transfer loads, change direction, or change the speed of the machine.

GEARS

Gears are toothed wheels used in pairs to transmit power or motion from one shaft to another. Motion is transferred using interlocking teeth of the gears. The meshing of teeth prevents any significant slippage as occurs with a belt on pulleys. Slippage is referred to as lost motion. The driving and driven shafts of gears must be in close proximity. Longer distances require the use of a chain and sprockets.

The rotation of one gear causes the opposite rotation of the meshing gear. The pinion gear is always the smallest of meshing gears. With two meshing gears, one gear rotating counterclockwise causes the other gear to rotate clockwise. An added third gear rotates the same direction as the first gear. See Figure 10-1.

Gears of equal diameter have a 1:1 ratio, and rotate at the same rate. For example, a complete revolution of gear A produces a complete revolution of gear B. If gear A is one-half the diameter of gear B, the larger gear B revolves 180° or half a revolution for every revolution of gear A. Gear A turns two revolutions for one revolution of gear B. Gears A and B have a 2:1 ratio. The ratio is determined by dividing the large gear pitch diameter by the small gear pitch diameter.

Gears are designed to have backlash between meshing teeth for maximum life and efficiency. *Backlash* is the amount of movement or play between the meshing teeth of gears. Backlash results when the tooth space exceeds the meshing tooth. Backlash is required between meshing gears to prevent full contact on both sides of the teeth. The space created allows lubricant between the contacting surfaces.

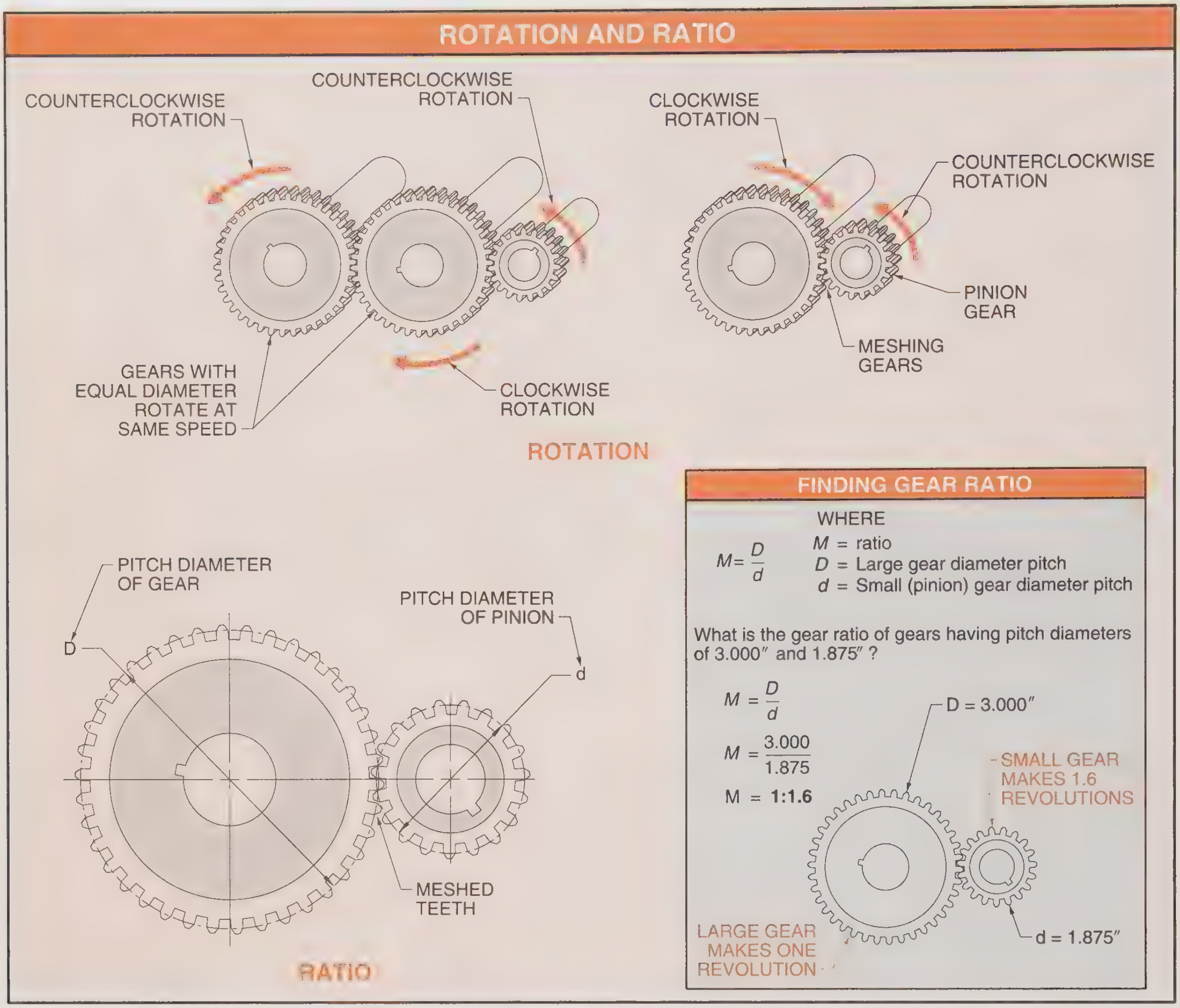


Figure 10-1. The size and number of gears determine the direction and rate of power transmitted.

Too little backlash can cause undesirable resistance resulting in the overheating or jamming of the meshing gears. Lubricant can become trapped at the base of the tooth. Excessive backlash can also cause problems if the load is reversed frequently.

GEAR SELECTION

Gears most commonly used in industry include spur, helical, herringbone, bevel, and worm gears. Gears are selected based on their specific application in the machine. See Figure 10-2.

Gears can be grouped into categories based on shaft orientation of meshing gears. Parallel shaft gears include spur, helical, herringbone, and internal gears.

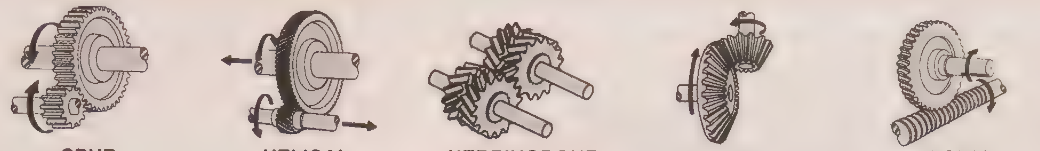
Intersecting shaft gears have shafts which commonly intersect each other at 90° in the same plane such as miter and bevel gears. Nonintersecting shaft gears have shafts that do not intersect in the same plane such as worm gears and some helical gears.

Spur Gears

Spur gears are gears with straight teeth that are parallel to the shaft axes. Spur gears are the most common gear type, and are used where the meshing gears are mounted on parallel shafts. They are suitable for speed ratios ranging from 1:1 to 1:6, and surface speeds of up to 1,000 feet per minute (fpm).

GEARS

GEAR TYPES



	SPUR	HELICAL	HERRINGBONE	BEVEL	WORM
SHAFT ORIENTATION	PARALLEL	PARALLEL	PARALLEL	INTERSECTING	NONINTERSECTING
TEETH/SHAPE ORIENTATION	STRAIGHT; PARALLEL TO SHAFT	STRAIGHT; ANGLED; NOT PARALLEL TO SHAFT	STRAIGHT; ANGLED; NOT PARALLEL TO SHAFT	TAPERED; MATING GEAR COMMONLY AT 90°	CURVED; SCREW THREAD FORM

GEAR SELECTION

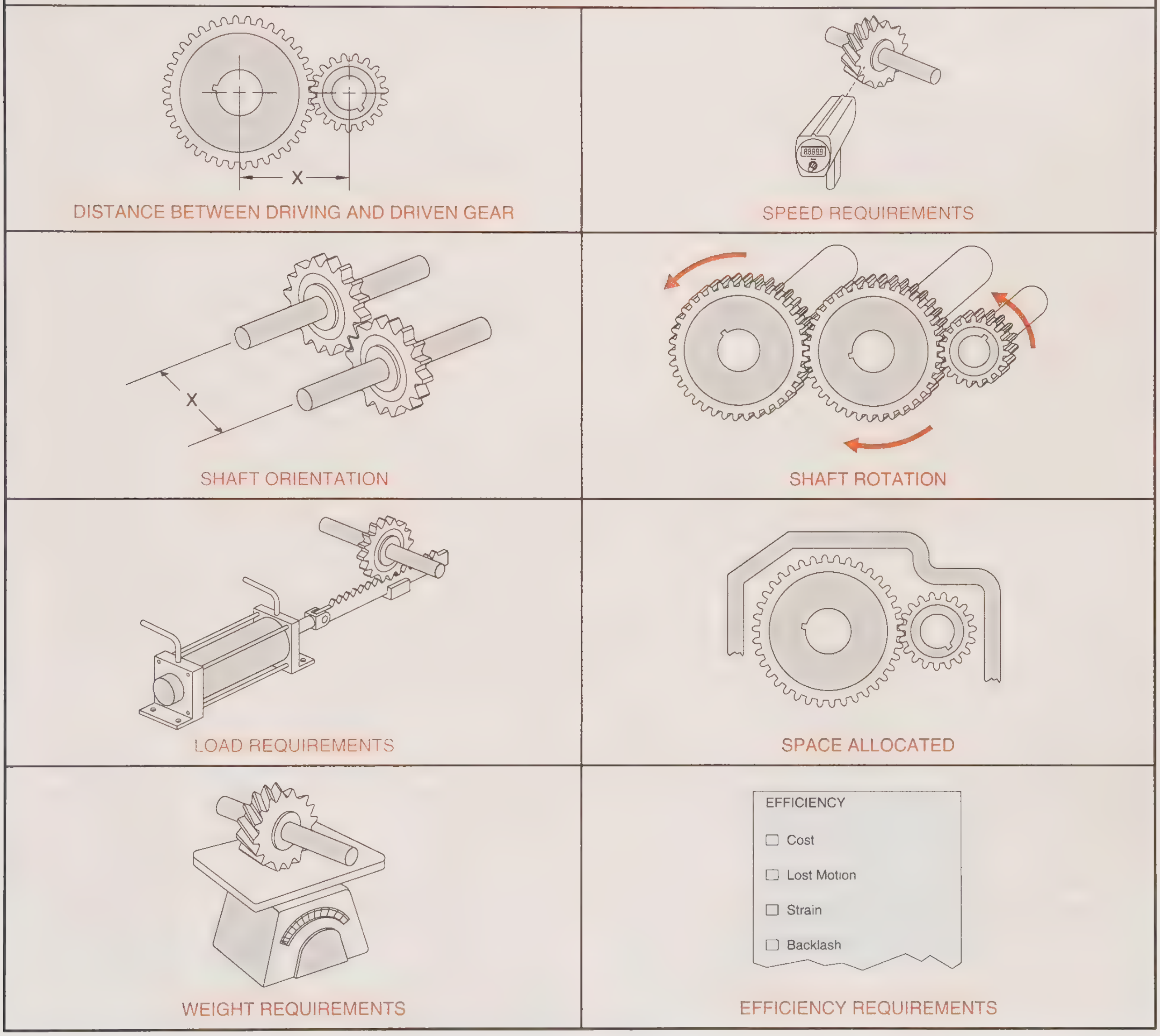


Figure 10-2. Gear selection is based on the specific application in the machine, and other factors such as cost and efficiency.

Internal gears are spur gears meshing on the inside circumference of a larger gear. This permits a larger ratio of reduction in a small space. A *rack* is a spur gear that is flat rather than concentric. A pinion is used with a rack to convert rotary motion into reciprocating motion. See Figure 10-3.

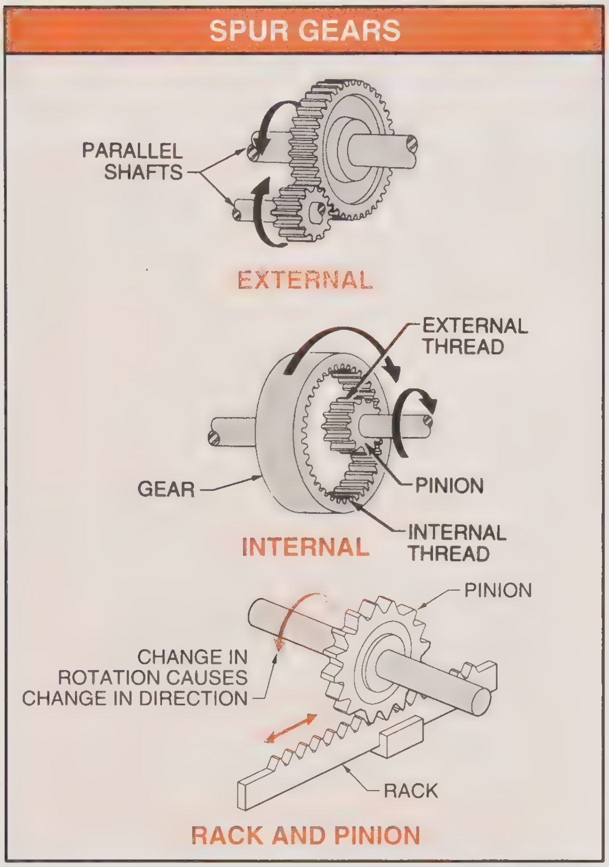


Figure 10-3. Spur gears are internal or external.

Spur gears commonly have a reduction ratio ranging from 1:1 to 8:1. Compound gearing, or using several gears, achieves a higher ratio of reduction. For example, a transmission in a car can obtain a larger range of ratios using compound gearing. However, when designing gear drive systems, lost motion, strains, and space limitations required by compound gearing must be considered.

Spur Gear Specification. Spur gears are designed by engineers and specified on the print using the American Gear Manufacturers Association (AGMA) standards. These standards provide specifications and tolerances for gear applications and their manufacture. Common spur gear parts are specified on the print using standard terminology. See Figure 10-4.

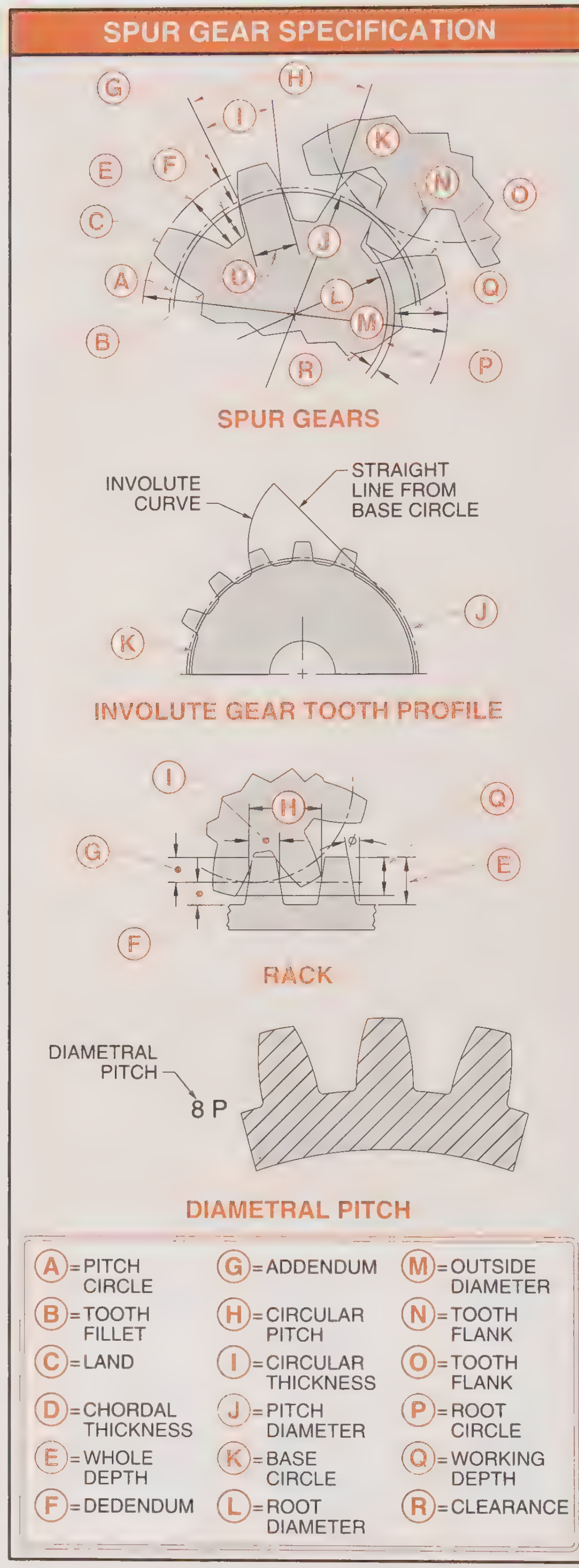


Figure 10-4. Gears are specified on prints using American Gear Manufacturers Association standards.

The *addendum* is the portion of the gear teeth between the pitch circle and the addendum circle. The *addendum circle* is the circle formed by the tops of the gear teeth. The addendum circle equals the pitch diameter plus twice the addendum, and is the same as the outside diameter of the gear.

The *base circle* of a spur gear is the circle from which an involute tooth curve is generated or developed.

Chordal thickness is the thickness of a tooth measured along the pitch circle.

Circular pitch is the distance between the centers of two adjacent teeth on the pitch circle.

Clearance is the space between the bottom of a tooth space and the tip of a tooth fully meshed into that tooth space.

The *dedendum* is the portion of the gear teeth which extends below the pitch circle.

Diametral pitch is the ratio of the number of teeth to the number of inches of pitch diameter. A 16-pitch gear has 16 teeth for each inch of pitch diameter. Pitch on the print followed by a number refers to diametral pitch (dp).

The *involute* is the curve formed by the path of a point on a straight line as it rolls along a convex surface. This is used to determine the geometric profile of gear teeth. The involute is formed by a curve. The involute shape changes with the diameter of the base circle.

The *land* is the flat surface on top of the tooth (top land) or the flat surface of the gear between adjacent teeth.

The *outside diameter* is equal to the pitch diameter plus twice the addendum.

The *pitch circle* is the imaginary circle located approximately halfway between the tops and the roots of the teeth. The pitch circle is the line of contact between two cylinders having the same ratios as the gears.

The *pitch diameter* is the diameter of the pitch circle.

The *root circle* is a circle formed by the bottom of the tooth spaces.

The *root diameter* is the diameter of the root circle.

The *tooth face* is the curved surface of a tooth located above the pitch circle and between the pitch circle and addendum circle.

The *tooth flank* is the curved surface of a tooth located below the pitch circle between the pitch circle and dedendum circle.

The *whole depth* is the total distance of the tooth from the dedendum circle to the addendum circle.

The *working depth* is the depth a tooth extends into the tooth space when in full mesh with proper clearance.

Spur gears are specified on prints with dimensions for pitch diameter, root diameter, and the gear blank profile. The gear teeth are not profiled but specified with the number of teeth and the diametral pitch. See Figure 10-5. To find pitch diameter, apply the formula:

$$D = \frac{N}{P}$$

where

D = pitch diameter

N = number of teeth

P = diametral pitch

For example, what is the pitch diameter of a gear having 18 teeth and a diametral pitch of 2?

$$D = \frac{N}{P}$$

$$D = \frac{18}{2}$$

$$D = \mathbf{9}$$

The outside diameter can be determined by applying the formula:

$$O = \frac{N+2}{P}$$

where

O = outside diameter

N = number of teeth

2 = constant

P = diametral pitch

For example, what is the outside diameter if a gear has 18 teeth and a diametral pitch of 2?

$$O = \frac{N+2}{2}$$

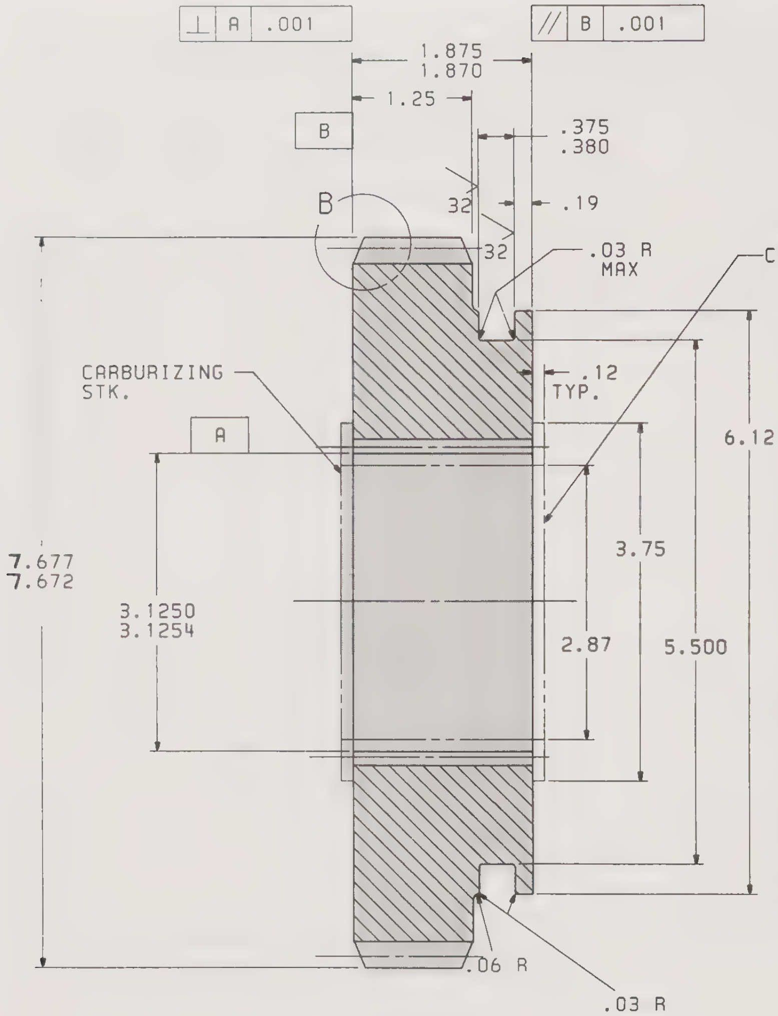
$$O = \frac{18+2}{2}$$

$$O = \frac{20}{2}$$

$$O = \mathbf{10}$$

Splines. *Splines* are a series of teeth or parallel surfaces machined into a shaft (external splines) or hub (internal splines). Spline tooth design specifications are similar to spur gears, and are commonly machined to half the depth. See ANSI Y14.7.2.

Splines provide positive transmission of power and permit assembly and disassembly as required. Splines transmit heavy loads without slippage where single keys would not provide sufficient strength. Splines are straight-sided or involute in design. The involute design is more common and is machined to match mating teeth on the shaft or hub. See Figure 10-6.



SPUR/HELICAL GEAR DATA	EXTERNAL
NUMBER OF TEETH	63
DIAMETRAL PITCH	8.4667
MODULE	3.000
TRANSVERSE DIAMETRAL PITCH	N/A
NORMAL PRESSURE ANGLE	20°
TRANSVERSE PRESSURE ANGLE	N/A
HELIX ANGLE	N/A
HAND OF HELIX	N/A
LEAD OF HELIX	N/A
STANDARD PITCH DIAMETER	7.4409
ROOT DIAMETER	7.1456
BASE CIRCLE DIAMETER	6.9922
ADDENDUM	.1181
ADDENDUM CORRECTION	0
CIRCULAR TOOTH THICKNESS	.1828 .1838
WHOLE DEPTH	.2776
SAP ROLL ANGLE,DEGREES	15.83°
CENTER DISTANCE	6.7323
CROWNED---YES/NO	YES
CLASS (AGMA 390.03)	12

Figure 10-5. Spur gear teeth are specified on the print using number of teeth and diametral pitch specifications.

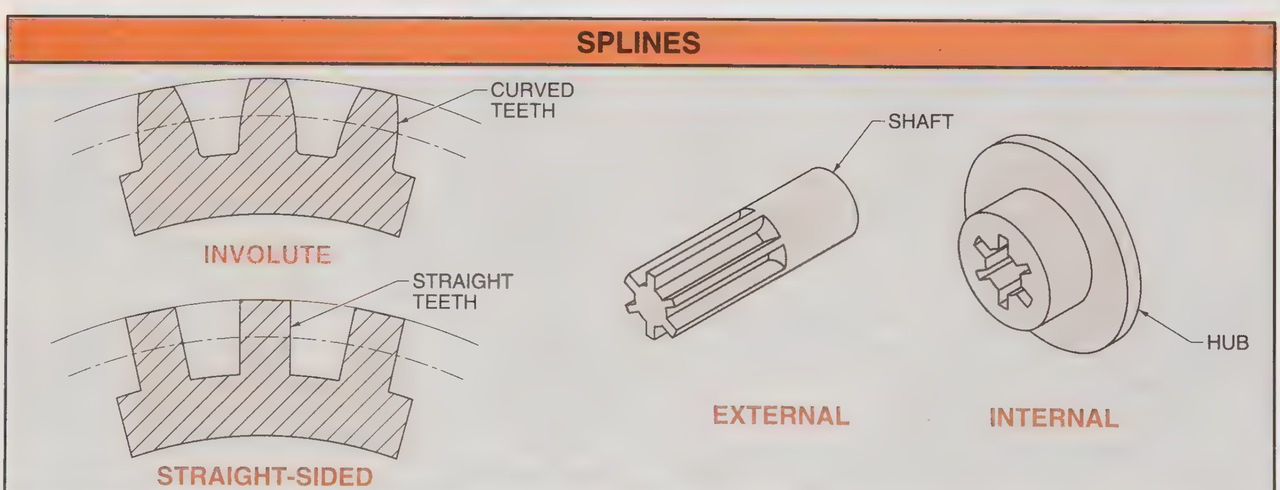


Figure 10-6. Splines prevent the rotation of a hub on a shaft.

Bevel Gears

Bevel gears are spur gears with tapered teeth used in applications where shaft axes intersect and are not parallel. Bevel gears resemble a cone shape rather than a cylinder shape with spur gears. Shafts of meshing bevel gears are most commonly positioned at 90°.

Bevel gears are manufactured in pairs to assure matching tapers. They are suitable for speed ratios ranging from 1:1 to 1:4. Bevel gears are primarily used in drive trains requiring shafts at right angles to each other. See Figure 10-7.

Miter gears are meshing bevel gears having the same number of teeth. Where smooth running is required to avoid noise at high speeds, the straight bevel gear is impractical. *Spiral bevel gears* are bevel gears that have curved teeth which provide smoother operation at high speeds.

Bevel gears are represented on a print in a section view. Required tooth cutting data is given. Bevel gears are specified on the print using the number of teeth and the diametral pitch. See Figure 10-8. The methods for using bevel gear formulas are the same for spur gear formulas.

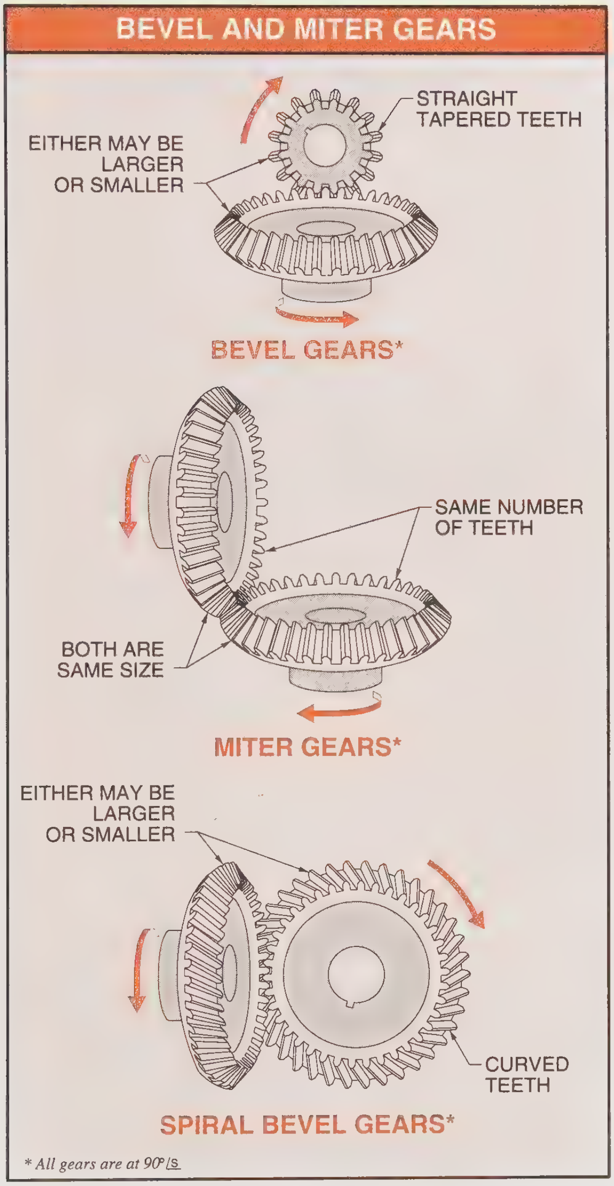
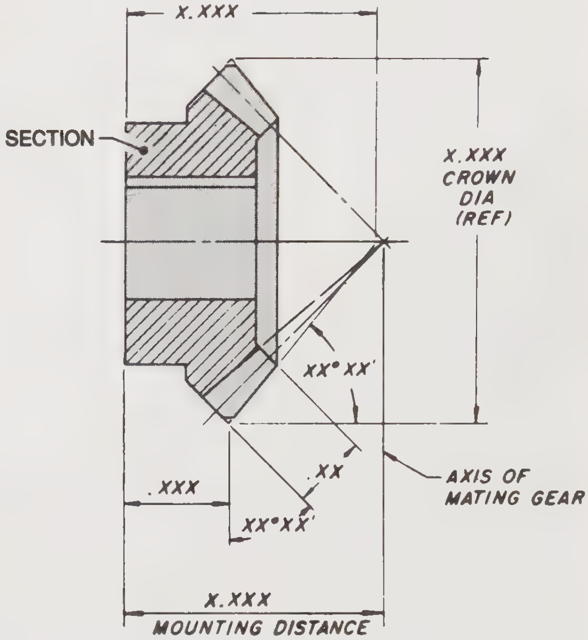


Figure 10-7. Bevel gears commonly transmit motion from shafts intersecting at 90°.



TOOTH CUTTING DATA

NUMBER OF TEETH	XX
DIAMETRAL PITCH	XX
PRESSURE ANGLE	XX°XX′
CONE DISTANCE	X.XXX
PITCH DIAMETER	X.XXX
CIRCULAR THICKNESS (REF)	.XXXX
PITCH ANGLE	X°XX′
ROOT ANGLE	XX°XX′
ADDENDUM	.XXX
WHOLE DEPTH (APPROX)	.XXX
CHORDAL ADDENDUM	.XXX
CHORDAL THICKNESS	.XXX
PART NUMBER OF MATING GEAR	XXXXX
TEETH IN MATING GEAR	XX
SHAFT ANGLE	XX°XX′
BACKLASH (ASSEMBLED)	.XXXX
TOOTH ANGLE (APPROX)	X°XX′
LIMIT POINT WIDTH	.XXX
TOOL EDGE RADIUS	XXX

Figure 10-8. Bevel gears are manufactured in pairs. Teeth specifications are shown in a section view on the print.

Helical Gears

Helical gears are spur gears with teeth that are not parallel to the shaft axis. They are manufactured in pairs so that their helix axes match. They are commonly used in drive trains. Helical gears are smoother in operation than spur gears.

The teeth on helical gears mesh with each other with a sliding motion. This results in more teeth in contact with each other at a given time. End thrust is produced because of the angle of the teeth. The amount of end thrust produced is proportional to the angle of the teeth. See Figure 10-9.

Herringbone gears are gears with two rows of helical teeth. Herringbone gears have parallel shafts and a pair of angled gear teeth that distribute the load transmitted. This keeps the gears aligned, and eliminates end thrust to provide quiet and efficient operation.

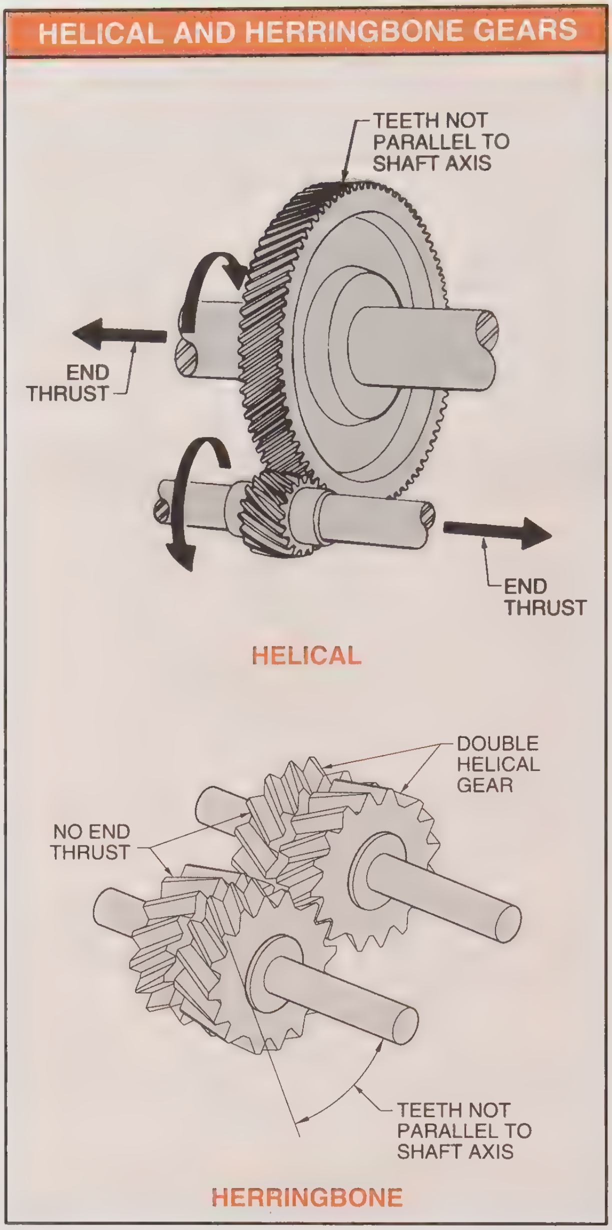


Figure 10-9. Helical gears have angled teeth which produce end thrust under load.

Worm Gears

Worm gears are gears that consist of a worm and worm gear used for large speed reduction. The worm has a screw thread from which it rotates the worm gear. The axes of the worm and worm gear do not intersect, and are not parallel.

The worm gear is commonly designed to advance one tooth for every revolution of the worm. This provides excellent speed reduction capability and smooth, quiet service. Worm gear teeth are cut on an angle to be driven by the worm.

The worm and worm gear are made with both single and multiple threads. Worm and worm gear dimensions are commonly represented in a full or half section. Specifications are included on the sectional views or in accompanying tables on the print. See Figure 10-10.

CAMS

A *cam* is a machine part that transmits motion using an irregular external or internal surface. Cams are useful in creating motions that would be difficult to reproduce using other mechanical parts. Cams are used with cam followers to transfer load, change direction, or change the speed of the machine. A *cam follower* is a machine part in contact with the cam which moves in a designated path.

The shape of the cam determines the direction and motion of the cam follower. Cams can be used with other cams to produce a combination of motions. Common cam designs include the plate cam, face cam, barrel cam, and yoke cam. See Figure 10-11.

Cams and their applications are defined using basic terminology. See Figure 10-12.

The *cam profile* is the actual shape or irregular surface features which actuate the cam follower.

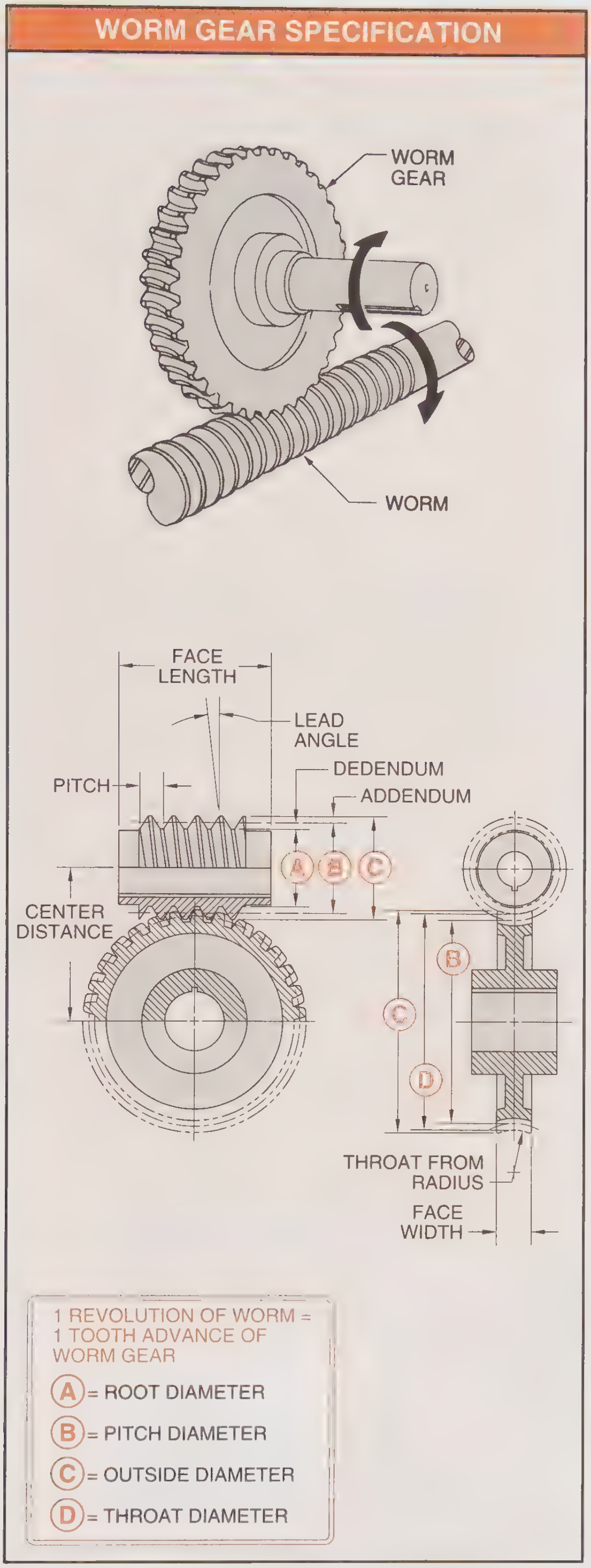


Figure 10-10. Worm gears are specified on the print with a section view detailing the gear teeth profile.

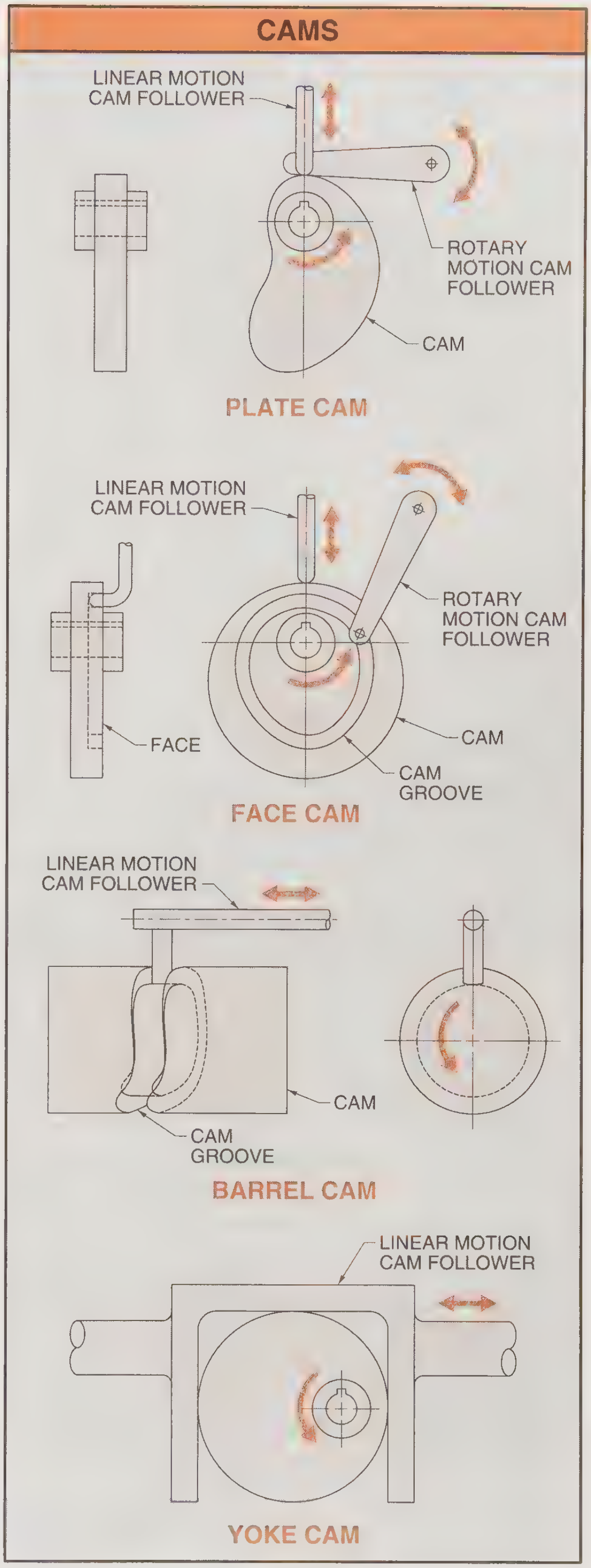


Figure 10-11. Cam motion required in the machine is accomplished by the cam design and cam follower.

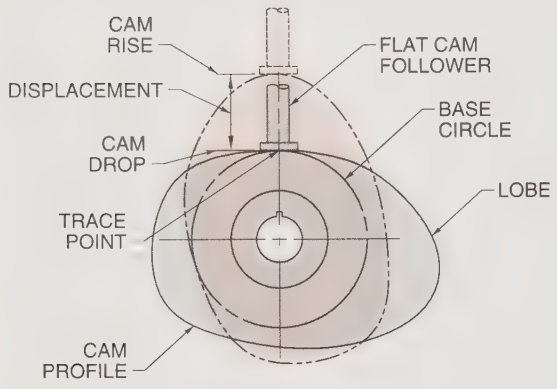


Figure 10-12. The cam profile shows the motion of the cam follower during machine operation.

The *cam displacement* is the maximum travel distance from the lowest to the highest point of the cam.

The *base circle* of a cam is the circle formed at the radius of the cam drop.

The *lobe* is the projecting part or parts of the cam which causes the cam follower to be displaced. Depending on the required motion, the cam may have several lobes to obtain the desired motions.

Trace point is the point of contact between the cam and cam follower.

Cams are designed for providing specific motion required by the machine part. The three common cam motions are uniform or constant-velocity, harmonic, and parabolic. See Figure 10-13.

Constant-velocity motion is a uniform, consistent rise-to-fall motion at a constant rate of speed during one revolution. The correlation between travel and rise is constant with speed.

Harmonic motion is a constant velocity without consistency in motion. Harmonic motion is used when a smooth start and stop motion is required. The gradual arcs at the end of the rises and falls provide a smoother motion with less shock to the part than constant-velocity motion.

Parabolic motion is a very smooth motion using a parabolic curve. This provides a uniform accelerated or decelerated motion. Motion created is not at a constant speed as in the constant-velocity or harmonic motion.

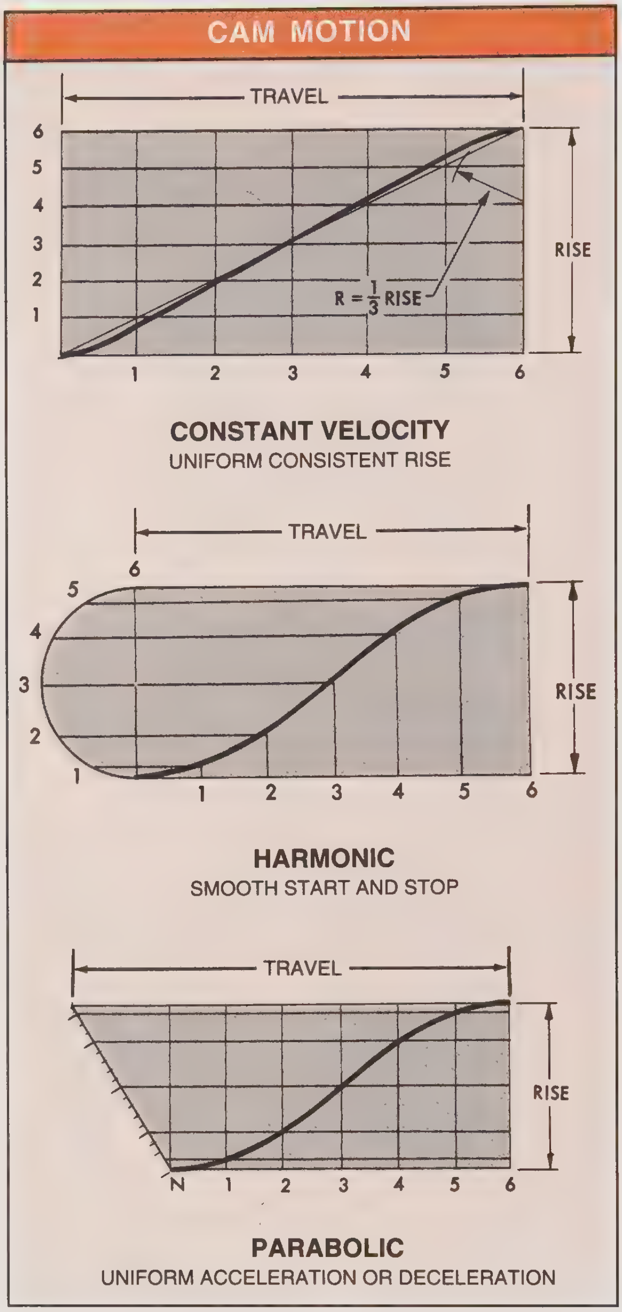


Figure 10-13. Cam and cam follower motion is designed to provide efficient operation and maximum life expectancy.

Cam Followers

Cam followers are designed for specific applications requiring certain loads and speeds. Common cam followers include flat, pointed, edge, spherical, and roller. Each of the cam followers must have a spring to maintain contact with the cam. See Figure 10-14.

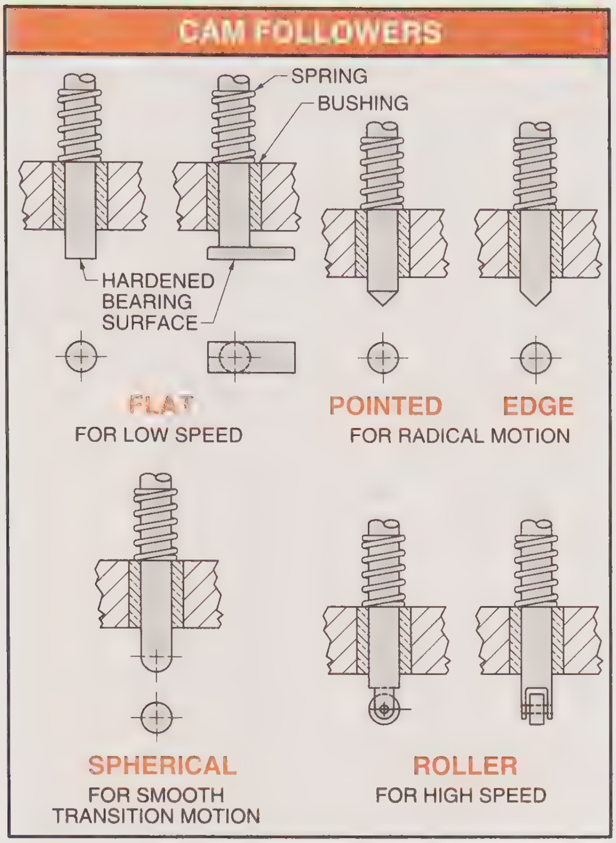


Figure 10-14. Cam followers are selected based on cam design and operating speed.

Flat cam followers are used primarily with cams that rotate slowly. Because of the surface contact, flat and point cam followers must have hardened bearing surfaces.

Pointed and edge cam followers are required when cam profiles have radical motion features. Spherical cam followers provide smooth transition motion in all directions, and mate with round grooves in the cam. Roller cam followers use a roller to provide the transmission of motion at higher speeds and minimum friction.

Cam Specification

Cams are designed to perform a specific motion or motions. Producing a cam to meet design specifications requires interpretation of the print information. Cam design is specified using a displacement diagram. A complete revolution of the cam (360°) is represented on the displacement diagram. *Dwell* is the time during the cam revolution in which there is no motion by the cam follower.

Plate cams are specified on a print showing the amount of motion or rise using radii. Barrel cams are specified on a print with a pattern that shows the motion of the cam as it would appear unrolled. See Figure 10-15.

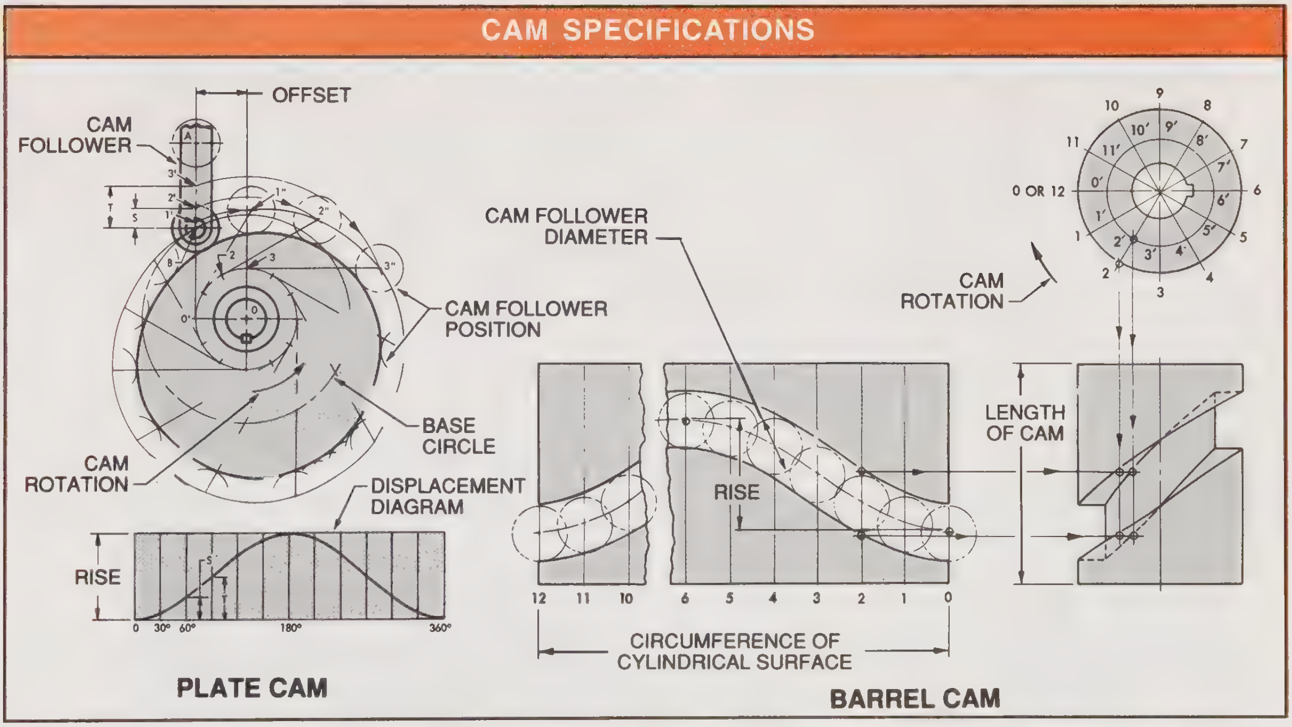
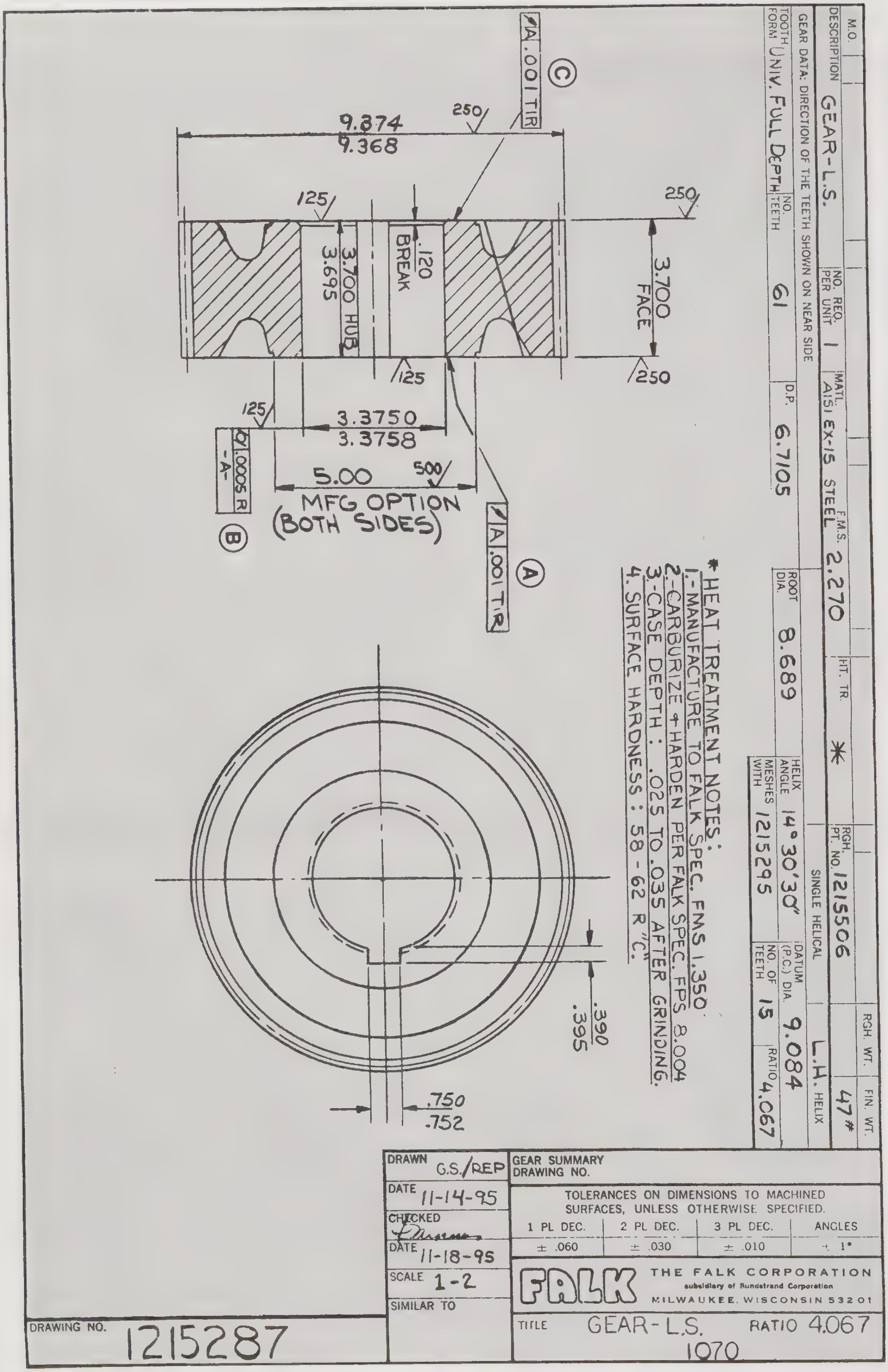


Figure 10-15. A displacement diagram traces the motion of the cam follower in one complete revolution of the cam.


M.O.
DESCRIPTION GEAR-L.S.
NO. REQ. PER UNIT 1
MATL. AISI EX-15 STEEL
F.M.S. 2.270
HT. TR. *
RGH. PT. NO. 1215506
RGH. WT.
FIN. WT. 47#
GEAR DATA: DIRECTION OF THE TEETH SHOWN ON NEAR SIDE
SINGLE HELICAL
L.H. HELIX
TOOTH FORM UNIV. FULL DEPTH
NO. TEETH 61
D.P. 6.7105
ROOT DIA. 8.689
HELIX ANGLE 14° 30' 30"
MESHES WITH 1215295
DATUM (P.C.) DIA. 9.084
NO. OF TEETH 15
RATIO 4.067
*HEAT TREATMENT NOTES:
1.-MANUFACTURE TO FALK SPEC. FMS 1.350
2.-CARBURIZE + HARDEN PER FALK SPEC. FPS 8.004
3.-CASE DEPTH: .025 TO .035 AFTER GRINDING.
4. SURFACE HARDNESS: 58 - 62 R "C."
9.374
9.368
A .001 TIR
C
250
125
3.700 FACE
3.700 HUB
3.695
.120 BREAK
125
3.3750
3.3758
5.00
500
MFG OPTION (BOTH SIDES)
.0005 R
-A-
B
A .001 TIR
A
.390
.395
.750
.752
DRAWN G.S./REP
DATE 11-14-95
CHECKED
DATE 11-18-95
SCALE 1-2
SIMILAR TO
GEAR SUMMARY DRAWING NO.
TOLERANCES ON DIMENSIONS TO MACHINED SURFACES, UNLESS OTHERWISE SPECIFIED.
1 PL DEC. ± .060
2 PL DEC. ± .030
3 PL DEC. ± .010
ANGLES ± 1°
FALK
THE FALK CORPORATION
subsidiary of Sundstrand Corporation
MILWAUKEE, WISCONSIN 53201
TITLE GEAR-L.S. 1070
RATIO 4.067
DRAWING NO. 1215287

GEAR 1070

Ø6
A1

Review Questions

Name ______________________________ Date ______________

Completion

______ 1. The ________ gear is the smallest of meshing gears.

______ 2. Gears of equal diameter which rotate at the same rate have a(n) ________ ratio.

______ 3. ________ gears have straight teeth that are parallel to the shaft axes.

______ 4. ________ gears are meshing bevel gears that have the same number of teeth.

______ 5. A(n) ________ is a machine part in contact with the cam that moves in a designated path.

______ 6. A(n) ________ is a spur gear that is flat rather than concentric.

______ 7. The ________ is the portion of the gear teeth which extends below the pitch circle.

______ 8. ________ bevel gears have curved teeth which provide smooth operation.

______ 9. ________ are used to produce motions that are difficult to produce with other machine parts.

______ 10. High speed applications commonly require ________ cam followers.

True-False

T F 1. The axes of the worm and worm gear are parallel.

T F 2. Helical gears are spur gears with teeth not parallel to the shaft.

T F 3. The lobe is the projecting part or parts of the cam.

T F 4. Parabolic cam motion is very smooth and uses a parabolic curve.

T F 5. Flat cam followers are designed for high speed applications.

T F 6. A displacement diagram is used to represent cam follower motion in one complete revolution of the cam.

T F 7. Backlash should be eliminated for maximum gear efficiency.

T F 8. Two meshing gears rotate in the same direction.

T F 9. The involute is a curve used to determine the geometric profile of gear teeth.

T F 10. Bevel gears are manufactured in pairs to assure matching tapers.

Multiple Choice

_____ **1.** _________ is the amount of movement or play between meshing gears.

A. Chordal thickness
B. Tooth flank
C. Backlash
D. Lost mesh

_____ **2.** Spur gears are commonly designed and specified using _________ standards.

A. AGMA
B. AISI
C. UNS
D. ASTM

_____ **3.** The _________ is the portion of the gear teeth between the pitch circle and the addendum circle.

A. addendum
B. involute
C. land
D. outside diameter

_____ **4.** Bevel gears have _________ teeth.

A. screw thread
B. tapered
C. curved
D. helical

_____ **5.** Cam _________ is the maximum travel distance from the lowest to the highest point of the cam.

A. profile
B. lobe
C. circle
D. displacement

_____ **6.** The _________ is the flat surface on top of the gear tooth.

A. dedendum
B. addendum
C. land
D. profile

_____ **7.** _________ have teeth machined into a shaft.

A. Cams
B. Splines
C. Lobes
D. Keys

_____ **8.** Shafts of meshing _________ gears are commonly positioned at 90°.

A. spur
B. helical
C. herringbone
D. bevel

_____ **9.** _________ gears have two rows of helical teeth.

A. Worm
B. Spur
C. Miter
D. Herringbone

_____ **10.** _________ is the ratio of the number of teeth to the number of inches of pitch diameter.

A. Diametral pitch
B. Pitch circle
C. Circular pitch
D. Root diameter

Matching — Gear Types

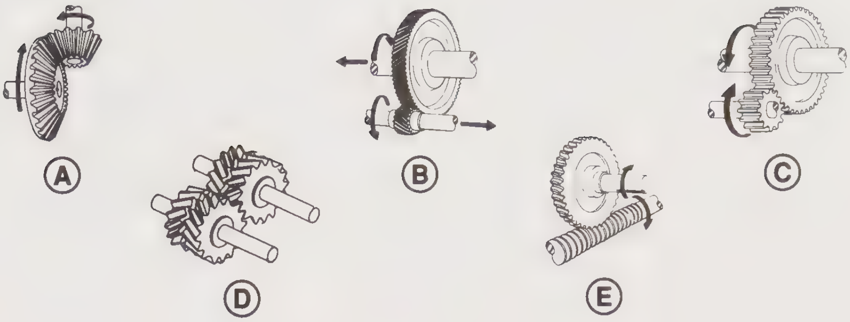
____________ **1.** Helical

____________ **2.** Bevel

____________ **3.** Herringbone

____________ **4.** Worm

____________ **5.** Spur



Matching — Rack Gear Specification

____________ **1.** Dedendum

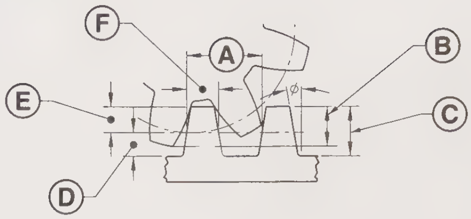
____________ **2.** Circular thickness

____________ **3.** Working depth

____________ **4.** Whole depth

____________ **5.** Circular pitch

____________ **6.** Addendum



Matching — Spur Gear Specification

____________ **1.** Land

____________ **2.** Chordal thickness

____________ **3.** Circular thickness

____________ **4.** Root diameter

____________ **5.** Base circle

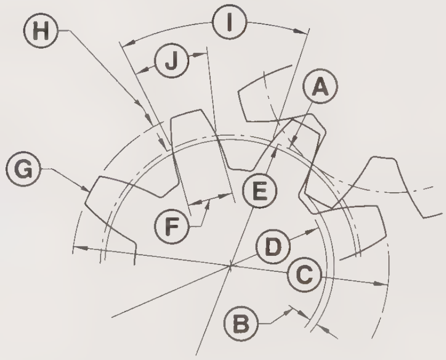
____________ **6.** Outside diameter

____________ **7.** Addendum

____________ **8.** Pitch diameter

____________ **9.** Clearance

____________ **10.** Circular pitch



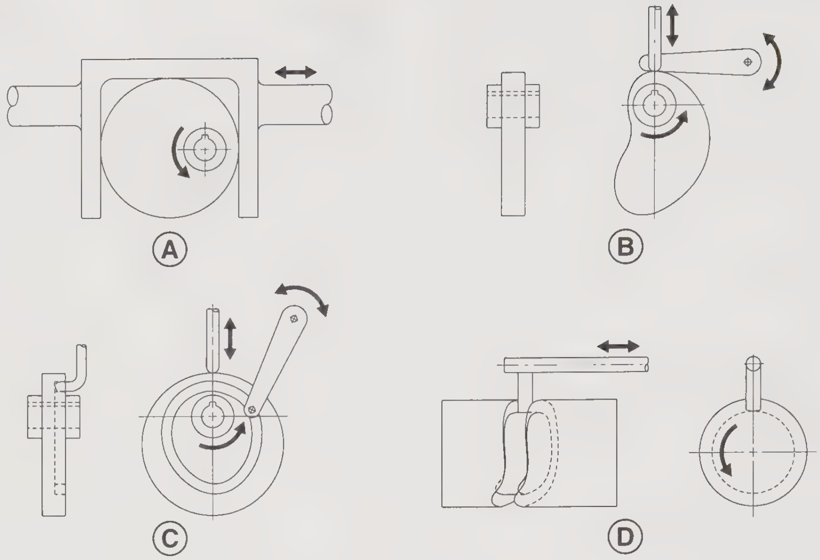
Matching — Cam Types

______ 1. Plate

______ 2. Barrel

______ 3. Face

______ 4. Yoke



Matching — Cam Specification

______ 1. Base circle

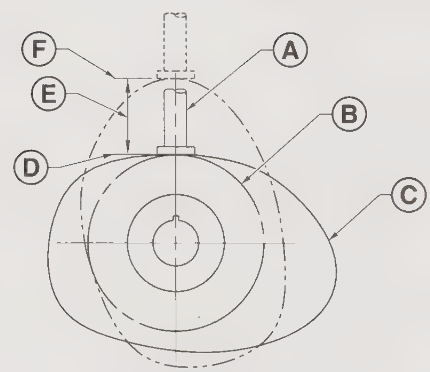
______ 2. Cam rise

______ 3. Cam follower

______ 4. Displacement

______ 5. Cam drop

______ 6. Lobe



◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Gear 1070 *(See page 208.)*

______ **1.** The specified width of the gear at the face is ________″.

______ **2.** A chamfer having a(n) ________″ depth is specified.

______ **3.** The keyseat is specified for a(n) ________″ maximum depth.

______ **4.** The ratio of the gears referred to on the print is ________.

______ **5.** The maximum outside diameter specified is ________″.

______ **6.** The gear has ________ number of teeth.

______ **7.** The gear shown on the print is designed to mesh with gear number ________.

______ **8.** The keyseat is specified for a(n) ________″ minimum width.

______ **9.** The tolerance for the hole is ________″.

______ **10.** The maximum hub width specified is ________″.

______ **11.** The gear has a diametral pitch of ________.

______ **12.** The maximum hole size specified is ________″.

______ **13.** Tooth form for the gear is ________.

______ **14.** The drawing number is ________.

______ **15.** The root diameter specified is ________″.

T F **16.** The rough part number for the gear is 1215287.

T F **17.** The 5″ dimension specified is a manufacturer's option.

T F **18.** The maximum allowable width of the gear at the face is 3.730″.

T F **19.** The minimum outside diameter specified is 9.368″.

T F **20.** The gear is case hardened to a depth of .025″ to .035″ after grinding.

______ **21.** Symbol ________ specifies circular runout tolerance on the chamfer side.

______ **22.** The gear shown on the print meshes with a gear that has ________ number of teeth.

______ **23.** The keyseat is specified for a(n) ________″ maximum width.

_____ 24. The helix angle specified is _____.

_____ 25. Symbol A specifies a tolerance zone of _____″.

_____ 26. The minimum hub width specified is _____″.

_____ 27. Finished weight specified for the gear is _____ lb.

_____ 28. The pitch circle diameter specified is _____″.

_____ 29. Symbol _____ specifies cylindricity tolerance.

_____ 30. The minimum hole size specified is _____″.

_____ 31. The gear is specified to be carburized and hardened per specification number _____.

_____ 32. Unless specified on the print, tolerances to one decimal place are _____″.

_____ 33. The material specified for the gear is _____ steel.

_____ 34. The keyseat is specified for a(n) _____″ minimum depth.

_____ 35. A tolerance of _____″ is specified for the outside diameter of the gear.

_____ 36. Symbol A references datum _____.

_____ 37. The _____ is indicated by a dashed line on the print.

_____ 38. The gear specified is a(n) _____ helical gear.

_____ 39. Unless otherwise specified, angular tolerance is _____°.

_____ 40. The gear is specified for a(n) _____ helix.

chapter 11

NUMERICAL CONTROL DOCUMENTS

Numerical control is widely used in modern machine shops. Numerical control documents are used to define the machining processes followed to produce a part. The prints are dimensioned and annotated in a way to make the programming easier.

NUMERICAL CONTROL

Numerical control (NC) is a process of controlling the motion of machine tools using a set of programmed commands. All common machine operations such as drilling, turning, milling, grinding, boring, tapping, cutting, etc. can be controlled using NC. Most modern machines use a computer to organize the program and relay the information to the machine. The most common computer numerically controlled (CNC) machines are machining centers and turning centers. See Figure 11-1.

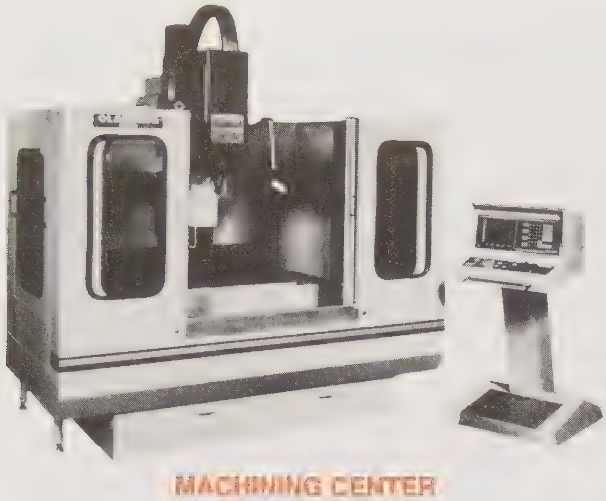
Functions

There are six basic functions included in the NC commands to control the operation of the machine. These are controlling position, controlling tools, establishing sequences, controlling speeds, monitoring machines, and controlling shutdown.

In addition, the CNC program allows for simplified changes in sequencing operations. Once the program is written, it can be easily modified to a new sequence by cutting and pasting the operations from one location to another.

Controlling Position. CNC programs control the position of the workpiece in relation to the cutter. This is done most commonly on milling and cutting operations where the cutter is fixed or moves in only one axis.

Controlling Tools. The tool or cutter is controlled through the program. The starting and stopping positions of the tool and the motion of the tool during the operations are controlled.



Clausing Industrial

Figure 11-1. Two numerically controlled machines are machining centers and turning centers.

Establishing Sequences. The steps of operation are controlled. Time intervals between operations are also specified.

Controlling Speeds. The CNC program controls the speeds of the movements and the cutter rotation if needed. Feed rates are also controlled.

Monitoring Machines. Most CNC machines have the ability to monitor themselves to assure accurate part production. They may be able to adjust to tool wear and other variables in the machining process. In addition, some are able to provide printouts of their operation.

Controlling Shutdown. Machine shutdown procedures are controlled by the CNC program. This includes parking the tool and moving the workpiece to a location where it can be removed.

NUMERICAL CONTROL COMMANDS

All NC programs use a series of commands to produce the desired part. These commands are stored in a punched tape or electronic format. All codes are input following standards recommended by the Electronics Industry Association (EIA) or the American Standard Code for Information Exchange (ASCII). The advantages to this form of tool control include repeatability, productivity, and efficiency.

The processes are repeatable because the same set of commands and operations is completed in the same manner every time. This allows for control of operations and close tolerances to be maintained.

Productivity is enhanced because operator error is virtually eliminated and fixed production times can be set and followed. Only shutdown for maintenance stops production. In addition, there is a reduced startup time on the production floor since all programs can be tested on the computer prior to sending the commands to the machines.

The NC programs allow for more efficient operation because of more rapid tool changes and reduced tooling requirements. Multiple tools are held in tool holders and can be automatically changed during the machining operations. Some turning centers have multiple tool holders to allow turning and boring operations to be completed without machine changes. Most machining and turning centers have more flexible means of holding the workpiece. This eliminates the need for costly tooling of jigs and fixtures.

Basis for Numerical Control

All NC programs are based on the Cartesian coordinate system. The *Cartesian coordinate system* is a system locating points in space defined by perpendicular planes. These planes are defined as X, Y, and Z axes. The X, Y, and Z axes form the primary method of locating points for NC programming. See Figure 11-2. All programming begins at the origin. For this reason many drawings are made with datum type dimensioning to allow for easier programming.

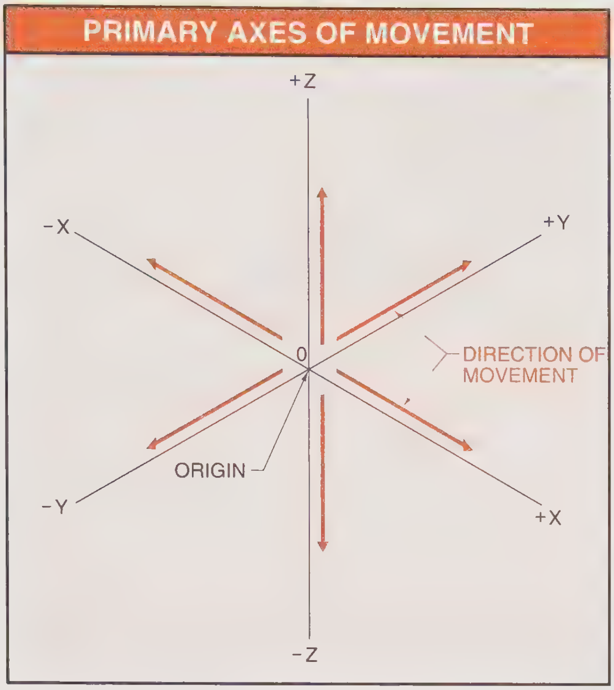


Figure 11-2. The primary axes of the Cartesian coordinate system are the X, Y, and Z axes.

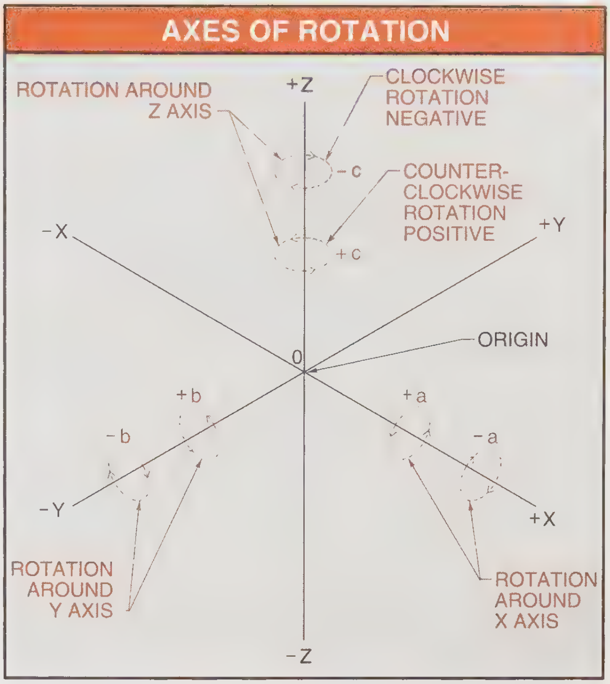


Figure 11-3. Axes of rotation provide three additional directions to control motion.

In addition to the three primary axes, the machining centers may have up to three additional axes of operation based on rotation around one of the primary axes. These are designated with a lowercase a for rotation around the X axis, b for rotation around the Y axis, and c for rotation around the Z axis. See Figure 11-3.

Travel along or around these axes allow numerically controlled machines to produce many different parts. Any machine will have the ability to control movement with reference to two, three, or more axes. A flame cutter controls the X and Y axes, while a turning center controls only the X and Z axes. Machining centers control at least the three primary axes. Many control the axes of rotation as well. See Figure 11-4.

Parts are programmed following two methods. These are incremental and absolute. See Figure 11-5.

Incremental Programming. *Incremental programming* is a method of numerical control where each movement originates at the last point where the machine stopped. This method of programming is less accurate due to the addition of tolerances for each subsequent movement.

Absolute Programming. *Absolute programming* is a method of numerical control where each movement is taken from the origin. With this method, there is no accumulation of tolerances as found in incremental programming.

Programming for Numerical Control

Numerically controlled machines are programmed to perform a series of operations using a code system. Each manufacturer may use a slightly different code structure but certain similarities exist. Each command starts with a letter to designate the type of action required and is followed by either a command code, distance, or speed specification. The letters used are G, X, Y, Z, A, B, C, S, T, and M.

G Codes. *G codes* are numerical control codes for preparatory commands used to set up the machine for a specific operation. They include such commands as G04, to dwell the machine at a certain point for a specified length of time. G04 × 40000 results in the machine pausing at a point for four seconds. In addition, G commands specify the type of programming used. G91 specifies incremental programming and G90 specifies absolute programming. G94 specifies feed rate.

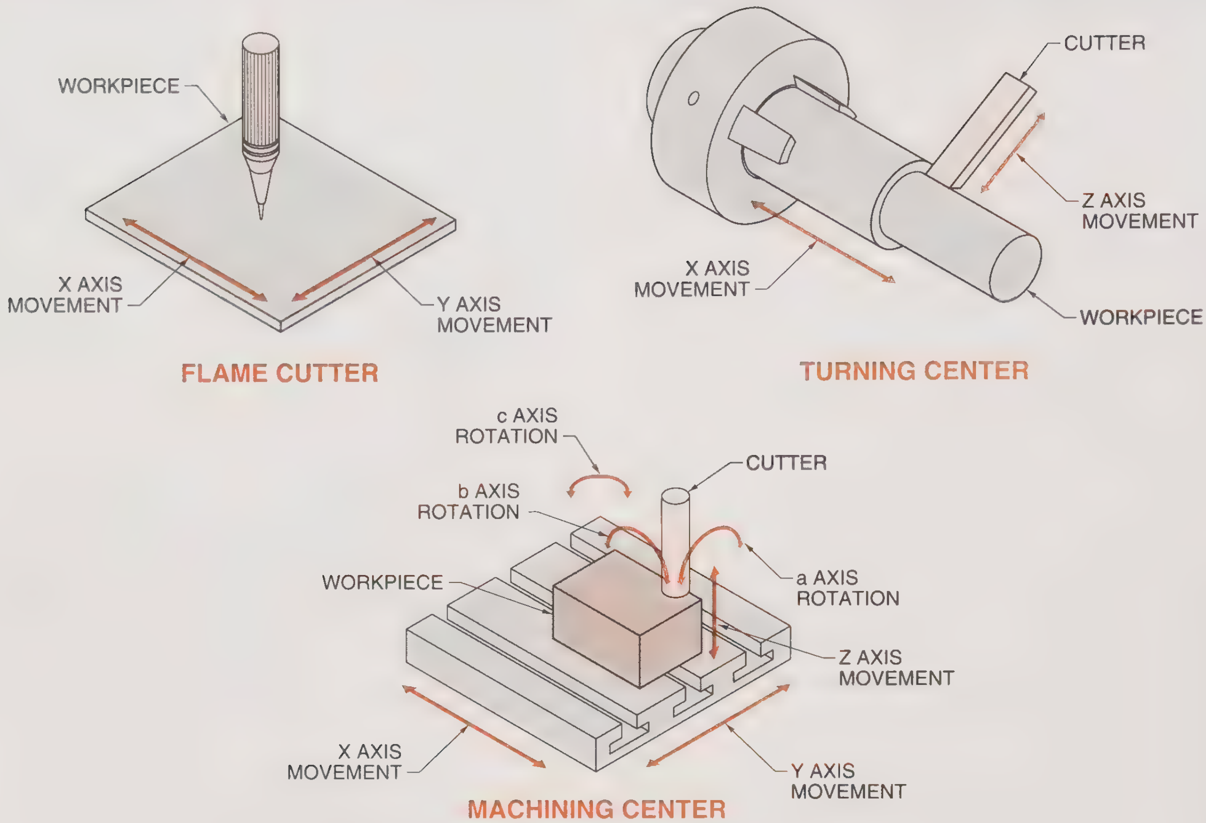


Figure 11-4. Machine tools control different axes of movement.

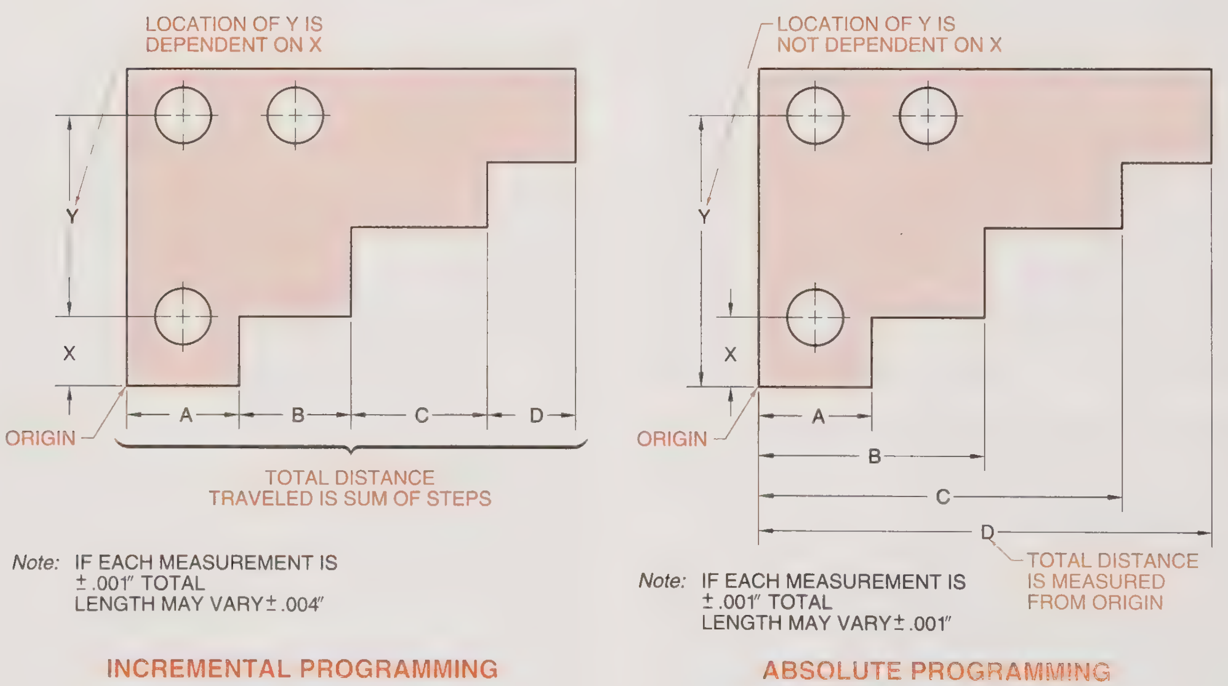


Figure 11-5. NC programming may be incremental or absolute.

X, Y, and Z Codes. *X, Y, and Z codes* are numerical control codes used to specify movement along one of the primary axes. The letter is followed by a positive or negative coordinate or distance to travel.

A, B, and C Codes. *A, B, and C codes* are numerical control codes used to specify rotation around one of the primary axes. These codes are followed by either a positive or negative direction of rotation in number of degrees. They are shown as lowercase letters on prints.

S Codes. *S codes* are numerical control codes used to specify spindle speed. This is either the speed in revolutions per minute for the cutter of a machining center, or the workpiece of a turning center.

T Codes. *T codes* are numerical control codes used to specify the turret stop of the desired tool. The tool offset is also specified.

M Codes. *M codes* are numerical control codes that control the machine actions. The M codes vary by manufacturer and type of machine. They are used to start and stop machine operations.

Types of Numerical Control Workpieces

The two types of NC-produced parts are point-to-point and contour. These are specified in one of nine groups depending on the complexity and method of programming. See Figure 11-6.

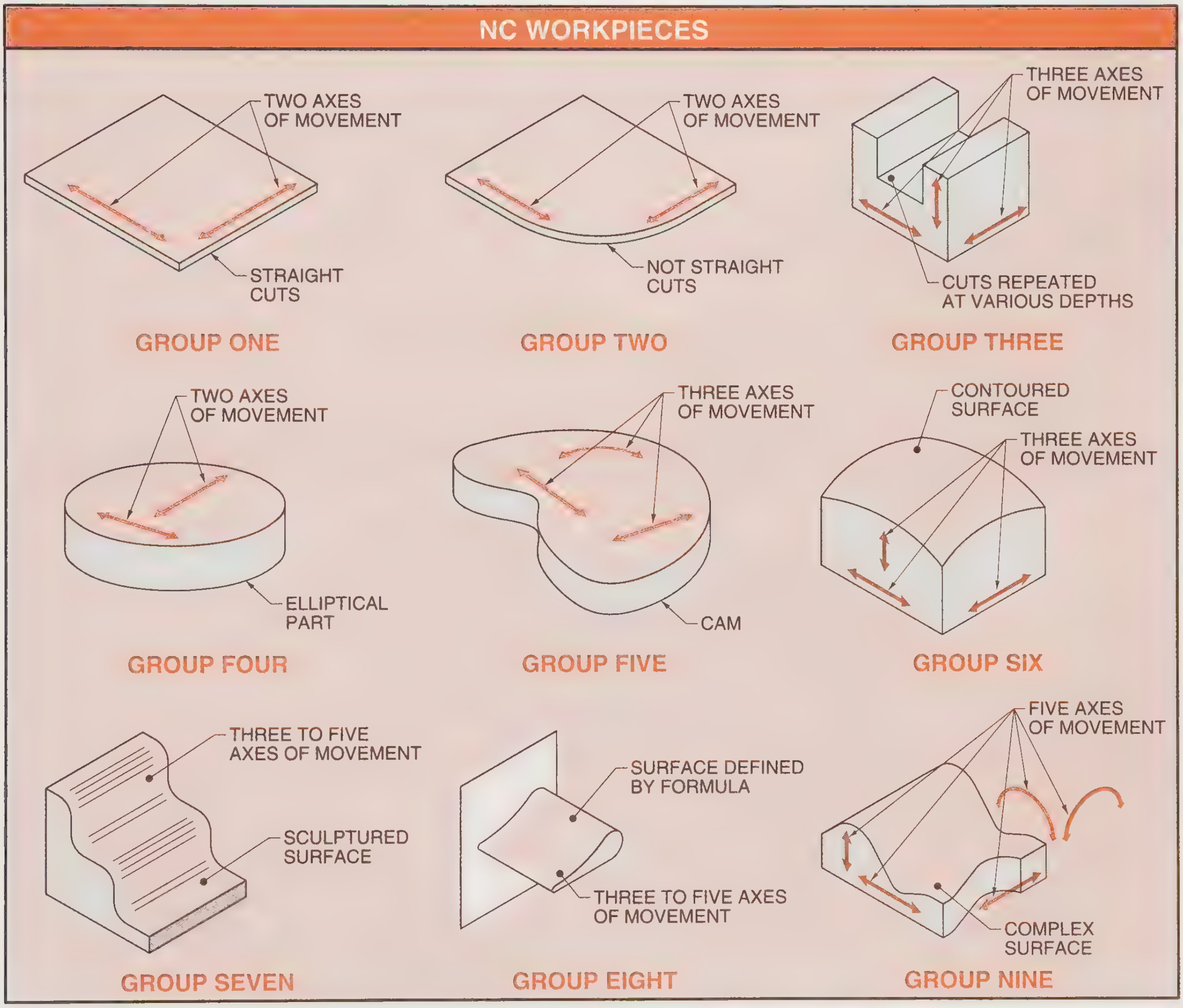


Figure 11-6. NC parts are divided into nine groups based on the complexity of the machining.

Group One. Group one NC programming includes straight cuts made point-to-point. These specify motion along two of the axes and may also specify a depth of cut.

Group Two. Group two NC programming includes single plane profile cutting. Motion is controlled along two axes with motion not in a straight line.

Group Three. Group three NC programming includes repetitive cuts. This includes cuts made to machine a recessed surface where multiple cuts within a given area are required.

Group Four. Group four NC programming includes complex curves created by using formulas. This includes such shapes as ellipses and other geometric shapes.

Group Five. Group five NC programming includes rotational motion. Parts such as cams fall into this group.

Group Six. Group six NC programming includes three-dimensional parts with contoured surfaces. The machine must be programmed along at least three axes simultaneously.

Group Seven. Group seven NC programming includes sculptured surfaces. Each surface is broken down to a mathematical definition.

Group Eight. Group eight NC programming includes formula-defined surfaces. This group includes such parts as turbine vanes and aircraft wings.

Group Nine. Group nine NC programming includes simultaneous five-axes motion. This is the most complex method of programming as all axes of motion must be controlled at the same time.

NUMERICAL CONTROL PRINTS

Prints created for NC parts have unique information not generally included with detail prints. Much of this information, such as tooling requirements, relates to the piece of equipment that is used to produce the part. These special features may be specified as part of the drawing or as notes with the drawing.

In addition to the normal information included on detail prints, the NC print also specifies the origin of the part. The origin is designated at a corner of the part or with a specified offset from the part. See Figure 11-7.

The drawing is generally oriented on the page so the plan view appears as the part appears in the machine. Often the cutter size and offset is specified. The operator's copy of the print may include cutter path information.

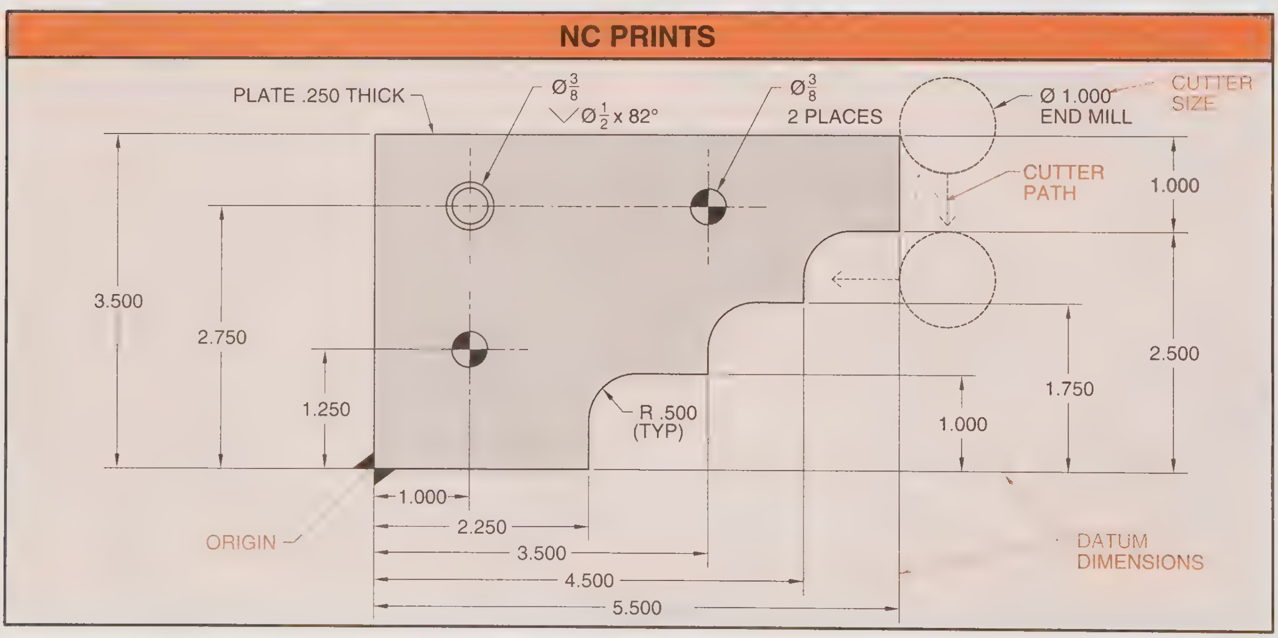


Figure 11-7. NC prints may specify the origin and cutter path and size information.

Review Questions

Name ______________________________ Date ______________

Multiple Choice

_______ **1.** A turning center controls the _________ axes.

A. X and Y
B. X and Z
C. X, Y, and Z
D. Y and Z

_______ **2.** _________ codes provide preparatory information for the program.

A. A, B, and C
B. G
C. M
D. S

_______ **3.** Group _________ parts have cuts in straight, point-to-point lines.

A. one
B. two
C. three
D. four

_______ **4.** A flame cutter controls the _________ axes.

A. X and Y
B. X and Z
C. X, Y, and Z
D. Y and Z

_______ **5.** Group _________ parts have repetitive cuts.

A. one
B. two
C. three
D. four

_______ **6.** Group _________ parts have single plane profile cuts.

A. one
B. two
C. three
D. four

_______ **7.** A machining center controls the _________ axes.

A. X and Y
B. X and Z
C. X, Y, and Z
D. Y and Z

_______ **8.** _________ causes the machine to dwell for a specified period.

A. G04
B. G90
C. G91
D. G94

_______ **9.** _________ indicates absolute programming is used.

A. G04
B. G90
C. G91
D. G94

_______ **10.** _________ codes are used to control spindle speed.

A. G
B. M
C. S
D. T

Completion

_______ 1. _______ dimensioning is used on NC prints.

_______ 2. The _______ coordinate system is the basis for NC.

_______ 3. Axes of rotation around the primary axes are designated with _______.

_______ 4. NC codes are input following EIA or _______ formats.

_______ 5. _______ programming is taken from the origin to a specified point.

_______ 6. CNC machines can control workpiece and _______ position.

_______ 7. Geometric shapes may be programmed using formulas in group _______ parts.

_______ 8. The primary axes in the Cartesian coordinate system are designated _______.

_______ 9. _______ programming is taken from the last point the machine stops to the next point of operation.

_______ 10. Group _______ parts have simultaneous five axes motion.

True-False

T F 1. CNC machines can monitor themselves to assure accurate production.

T F 2. Feed rates must be manually set on CNC machines.

T F 3. Numerically controlled processes are more repeatable than conventional processes.

T F 4. Tooling requirements may be specified on NC prints.

T F 5. The origin used for programming is determined by the machine operator.

T F 6. Turning centers have a single tool holder.

T F 7. CNC machines require the operator to shut down operations.

T F 8. NC prints may include cutter path information.

T F 9. NC machines have slower tool changes than conventional machine tools.

T F 10. NC program codes may vary by manufacturer.

◎ .0005 TIR A

Trade Competency Test

Name ______________________________ Date ______________

Bar

_______ **1.** The drilled holes are _______ to datum C.

_______ **2.** The maximum length for the Bar is _______″.

T F **3.** The origin is at the intersection of datums A, B, and C.

T F **4.** Incremental dimensioning is used.

T F **5.** There is 1.500″ between centers of the drilled holes.

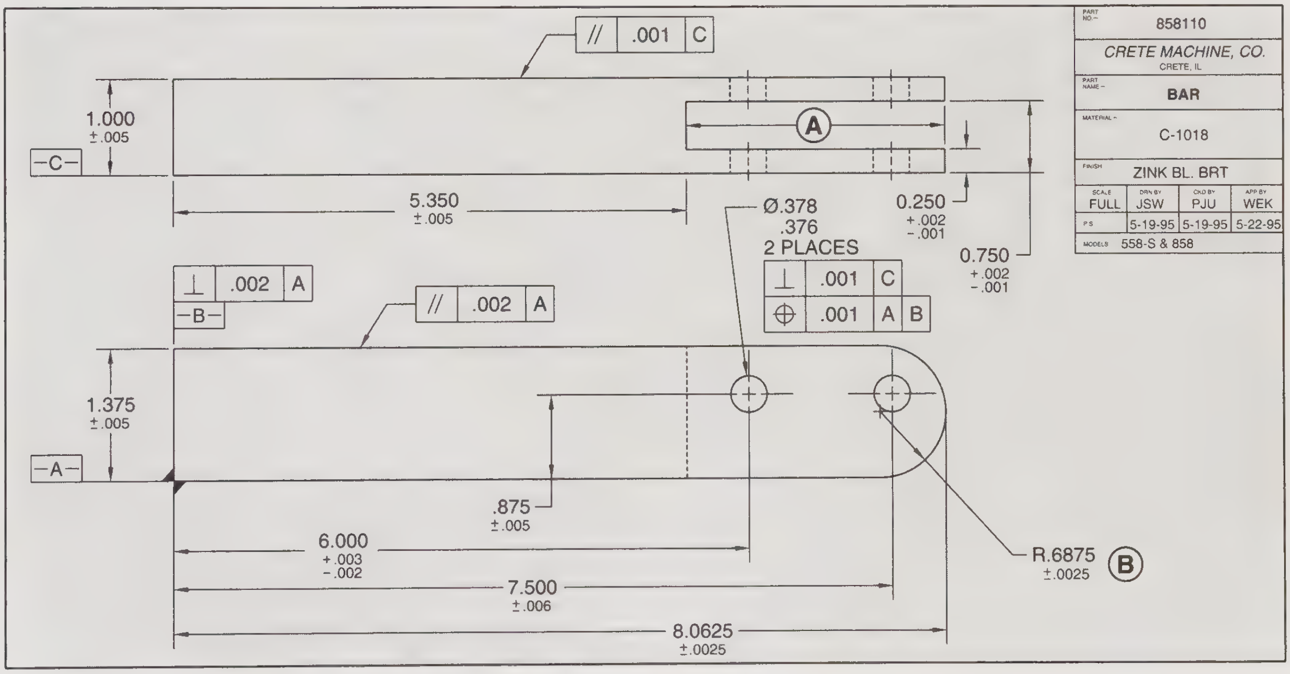
_______ **6.** Depth A is _______″ at its maximum depth.

_______ **7.** The drilled holes are positioned with reference to datum(s) _______.

_______ **8.** At a maximum material condition, the diameter of the drilled holes is _______″.

T F **9.** The drilled holes are .875″ from datum B.

_______ **10.** The center for radius B is _______″ from datum B.



BAR

Bearing

_______ **1.** The origin is located at _______.

_______ **2.** The Bearing is oil impregnated with _______.

_______ **3.** The inside diameter is _______ with diameter B.

_______ **4.** Angle C may be a maximum of _______°.

_______ **5.** The outside diameter has a tolerance of _______″.

T F **6.** All chamfers are 1⁄64″ deep.

T F **7.** All decimal dimensions have a tolerance of ±.101″.

T F **8.** The drawing was revised on 4-19-95.

T F **9.** The diameter of datum A is from .8290″ to .8300″.

_______ **10.** Before revision, the diameter at A1 was _______″.

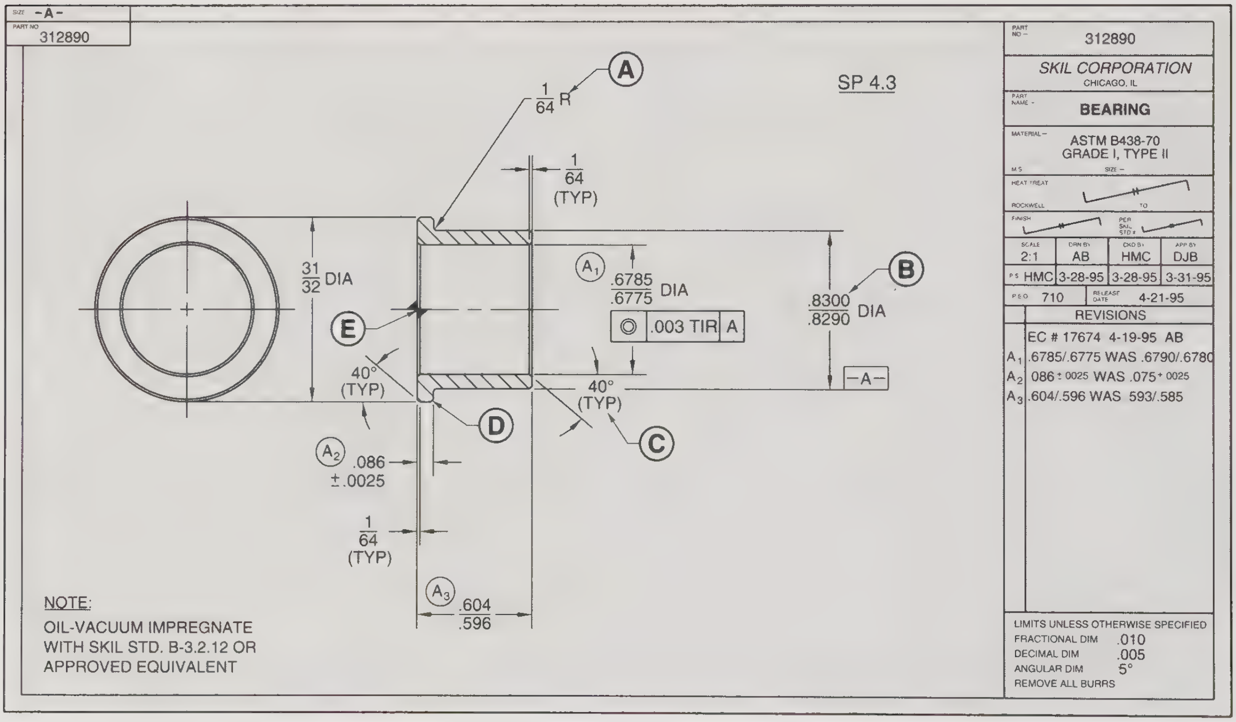
_______ **11.** The collar at D is _______″ thick.

_______ **12.** The drawing was made by _______.

_______ **13.** The bearing is made with _______.

T F **14.** The drawing is made at full scale.

T F **15.** Radius A is 1⁄32″.



BEARING

chapter **12**

SPECIALIZED PRINTS

Trade Test 1 — Support, UV 1″–18″ Arm
Trade Test 2 — A1-ACC Adaptor
Trade Test 3 — Bearing Retainer Assembly
Trade Test 4 — Holder–Punch
Trade Test 5 — Detail, Bottom Die Holder
Trade Test 6 — O.D. Grinder
Final Exam — 3.5 Vise

ANSI

The American National Standards Institute, Inc. (ANSI) validates the general acceptability of the work of support organizations to develop American National Standards. While ANSI is an impartial organization that does not develop standards itself, it does guarantee that support organizations used democratic procedures to reach consensus of a standard's provisions and that these provisions neither conflict with nor unnecessarily duplicate other national standards.

Support organizations consist of professional/technical societies, trade associations, and consumer and labor groups. Typical support organizations that are directly concerned with machines trades printreading include, but are not limited to:

ASME	American Society of Mechanical Engineers
AGMA	American Gear Manufacturers Association
AWS	American Welding Society
CAM-I	Computer Aided Manufacturing International
RIA	Robotic Industries Association
SAE	Society of Automotive Engineers

Other support organizations such as the Power Tool Institute (PTI), American Society for Nondestructive Testing (ASNT), Fluid Controls Institute (FCI), and many others are also involved in the development of standards.

American National Standards are intended as guides to aid manufacturers, consumers, and the general public. The existence of a standard does

not, however, preclude any company from following procedures which do not conform to the standard.

Therefore, while the drawings for many prints are developed based on ANSI standards, other drawings may not always reflect all current standards.

Experienced printreaders recognize that the application of standards vary, so they study prints very carefully to determine the manufacturer's intent. For example, while one manufacturer uses CENT. as an abbreviation, ANSI Y1.1, *Abbreviations* does not include CENT. as an abbreviation. Careful study of the manufacturer's print shows that CENT. is intended as the abbreviation for center.

PRINTS

Prints in Trade Tests 1–6 and the Final Exam represent the broad range of prints used in industry. Prints include:

Support, UV 1″–18″ Arm

Orthographic and sectional views are featured. Geometric tolerances are specified. Metric dimensions are given.

A1-ACC Adaptor

Orthographic and sectional views are featured. Geometric tolerances are specified. Metric dimensions are given.

Bearing Retainer Assembly

Detail and assembly prints show orthographic and sectional views of the parts. Geometric tolerances are specified. Comprehensive notes specify features.

Holder–Punch

Orthographic and sectional views describe the part. Surface finish and geometric tolerances are specified. Simplified location dimensions give center points of all holes.

Detail, Bottom Die Holder

Orthographic and sectional views feature fractional and decimal dimensions. Finish marks indicate milled surfaces. Comprehensive notes detail holes.

O.D. Grinder

Detail and assembly prints show orthographic views of the parts for the Front Grinding Guide Assembly. Decimal dimensions to four places emphasize the precision of the parts. Geometric tolerances are specified. Surface finish and threaded holes are indicated.

3.5 Vise

Detail and assembly prints show orthographic and sectional views of the 3.5 Vise. A comprehensive material list is included. Geometric tolerances are specified. Part numbers relate details to the assembly. This is an excellent project for the machine shop.

// .005 A

Trade Test 1

Name ______________________________ Date ______________

Support, UV 1″–18″ Arm *(See page 241.)*

______ **1.** The thread form for the two studs is _________.

A. UNC C. UNEF
B. UNF D. NPT

______ **2.** A(n) _________ auxiliary view shows details of the obround.

A. full C. double
B. partial D. revolved

______ **3.** _________ welds are typical at four corners.

______ **4.** The inside bend radius is _________″.

______ **5.** _________ lines are drawn to show sections AA and BB.

______ **6.** The diameter of the threaded stud is _________″.

______ **7.** The tolerance for all holes is _________″.

______ **8.** The bottom piece is bent at two _________° angles to form the sides.

______ **9.** The overall length of the Support, not including the studs, is _________″.

______ **10.** Side A measures _________″.

______ **11.** The maximum center-to-center dimension of B is _________″.

______ **12.** The minimum overall height of the Support is _________″.

______ **13.** The dimension of the bottom piece at C is _________″.

______ **14.** The view shown at D is the _________ view.

______ **15.** The margin-to-margin dimensions of the sheet for the drawing of the Support is _________.

T F **16.** The studs may be zinc plated or stainless steel.

T F **17.** Section BB is taken from the top view.

T F **18.** The Support is drawn to full scale.

______ **19.** The center-to-center distance between E and F is _________″.

______ **20.** The two cutting planes are _________″ apart.

T F **21.** All obrounds are the same size.

T F 22. All dimensions have a tolerance of .030″.

T F 23. Each corner of the Support is welded.

T F 24. Section AA gives location dimensions for obrounds.

__________ 25. Section BB is taken _________″ from the left end of the Support.

__________ 26. Center lines G and H are _________″ apart.

__________ 27. The drawing number for the Support is _________.

T F 28. All external threads are covered before painting.

T F 29. The material for the Support is 0.598″ thick.

T F 30. All dimensioning on the drawing is unidirectional.

__________ 31. The maximum distance between centers of the threaded studs is _________″.

__________ 32. There are _________ obrounds on the Support.

__________ 33. The drawing was completed on _________.

__________ 34. The Support is finished in _________.

__________ 35. The two ∅0.281 holes have a minimum diameter of _________″.

__________ 36. The drawing was approved by _________.

T F 37. The ∅.312 holes are located 0.375″ from the end of the Support.

T F 38. The center of the studs are located 0.387″ from the bottom of the Support.

T F 39. The obrounds at E and F are equally spaced in from the end of the Support.

T F 40. The studs have 20 threads per inch.

$\boxed{//}\boxed{.005}\boxed{A}$

Trade Test 2

Name______________________________ Date ______________

A1-ACC Adaptor *(See page 242.)*

________ **1.** All linear dimensions are given in ________.

________ **2.** The overall thickness of the Adaptor is ________ mm.

T F **3.** The Adaptor is manufactured from cast iron.

T F **4.** The cutting plane line is offset to pass through more internal features.

________ **5.** The Adaptor must be cylindrical within a(n) ________ mm tolerance zone.

________ **6.** Hole C must be perpendicular to datum ________ within .001 mm.

________ **7.** Datum B has a maximum diameter of ________ mm.

T F **8.** The angular tolerance, unless otherwise specified, is 0°15′.

T F **9.** The project engineer approved the print on the same day it was checked.

________ **10.** The counterbored hole at A is ________° from the horizontal.

________ **11.** Circle B is referred to as a(n) ________ circle.

________ **12.** The blind hole must be at a(n) ________ within a .002 tolerance zone with regard to datum B.

________ **13.** Surface F has a total runout within a(n) ________ tolerance zone around datum B.

________ **14.** All true position tolerances are toleranced around datum ________.

________ **15.** The counterbored hole at C has a counterbore depth of ________ mm.

T F **16.** Section A-A is a removed section.

T F **17.** The maximum decimal tolerance, unless otherwise specified, is ±.005″.

T F **18.** The Adaptor is polished to a brilliant finish.

T F **19.** The overall diameter of the Adaptor is 133 mm.

T F **20.** General use section lines show where the cutting plane was passed through the object.

________ **21.** The maximum diameter of D is ________ mm.

________ **22.** An M5 × 0.8 thread, 8 mm deep is used in ________ places on the Adaptor.

________ **23.** The drawing number of the Adaptor is ________.

______ **24.** The print is drawn to ________ scale.

______ **25.** The back edge contains a 2 mm × ________° chamfer.

______ **26.** The maximum diameter at E is ________ mm.

T F **27.** The bottom recess slopes 7°.

T F **28.** Datum A is parallel within a tolerance zone of .01 mm.

______ **29.** The maximum distance the bolt circle for hole C may be from datum axis B is ________ mm.

______ **30.** The minimum distance the center of threaded hole G may be from datum axis B is ________ mm.

______ **31.** Piedmont Tool Co. is located in ________.

______ **32.** The six tapped holes are located on a(n) ________ mm bolt circle.

______ **33.** The blind hole on the 105 BC is ________ mm deep.

T F **34.** The centers of the ∅5.5 holes are located 6 mm from datum A.

T F **35.** The back view of the object is represented by a simplified view.

T F **36.** There are four ∅12 holes drilled on the 105 BC.

T F **37.** The drawing was checked by TRE.

T F **38.** The drawing may be scaled to determine the overall size.

______ **39.** Hole H may be a maximum of ________° offset from the vertical centerline.

______ **40.** The project engineer was ________.

// .005 A

Trade Test 3

Name________________________________ Date ______________

Bearing Retainer Assembly *(See pages 243 – 246.)*

T F **1.** A half section is shown of the Left Retainer.

_________ **2.** Sheet 1 of 4 shows a(n) _________ drawing of the Bearing Retainer Assembly.

_________ **3.** The bearing has a(n) _________″ × 45° chamfer on both ends.

_________ **4.** The maximum spherical diameter of the Right Retainer is _________″.

T F **5.** Rivets are purchased items for the Bearing Retainer Assembly.

T F **6.** The bearing should show movement within a weight range of 5 to 30 oz only.

_________ **7.** A(n) _________ section is shown of the Right Retainer.

_________ **8.** The Bearing Retainer Assembly fits a(n) _________″ diameter pin.

_________ **9.** The Bearing is made of Grade I, Type II _________.

_________ **10.** When assembled, the Right Retainer must be flat within a(n) _________″ tolerance zone.

T F **11.** The release date of the Bearing print is 7-20-95.

T F **12.** No burrs are permitted on the Right Retainer.

T F **13.** No burrs are permitted on the Left Retainer.

_________ **14.** The overall height of the Left Retainer is _________″.

_________ **15.** The overall length of the Right Retainer is _________″.

T F **16.** The three .116 DIA holes of each retainer align with one another.

_________ **17.** The typical radius of Retainer corners is _________″.

_________ **18.** The thickness of the Right Retainer is _________″.

_________ **19.** The Left Retainer is made of hardened _________ steel.

T F **20.** All drawings of the Bearing Retainer Assembly are drawn at full scale.

T F **21.** Part No. 318714 was formerly Part No. 341456.

T F **22.** The overall diameter of the Bearing is .502″.

T F **23.** RSW drew Part No. 318714 on 7-14-95.

T F **24.** All bearings are tumbled.

__________ **25.** Rivet heads are placed on the side of the assembly containing the __________ Retainer.

__________ **26.** Part No. __________ is the only part in which alternate material may be used.

__________ **27.** Part No. 318717 is built to Skil standard __________.

__________ **28.** Omnilube __________ is used to oil vacuum impregnate the Bearing.

__________ **29.** The radius at B on the Right Retainer is __________″.

__________ **30.** The stock size at A on Part No. 318717 is __________″.

T F **31.** Fractional dimensions are limited at .010″ on all sheets unless otherwise specified.

__________ **32.** The hole at A on Part No. 318716 has a diameter of __________″.

__________ **33.** Datum A is __________″ in diameter in a maximum material condition.

__________ **34.** The Right Retainer has a thickness tolerance of __________″.

__________ **35.** When all parts are at maximum material condition, there is __________″ clearance between the Bearing slot and the tab on the Left Retainer.

__________ **36.** The three horizontally-aligned holes on Part No. 318717 are located a maximum of __________″ from the centerpoint of the Left Retainer.

__________ **37.** All decimal dimensions have a limit of __________″ unless otherwise specified.

__________ **38.** The maximum stock thickness of Part No. 318716 is __________″.

__________ **39.** The Right Retainer is made of cold-rolled strip __________.

__________ **40.** Three clips on the Retainer are __________″ wide each.

T F **41.** The flatness of the Right Retainer can vary .001″ less when assembled than when manufactured.

T F **42.** Surface A on the Bearing is cylindrical with datum A within a .010″ tolerance zone.

__________ **43.** The Retainer has a(n) __________ finish.

T F **44.** The approval date for all drawings is the same.

__________ **45.** The Left Retainer is __________ within a .010″ tolerance zone.

// .005 A

Trade Test 4

Name ____________________ Date ____________

Holder–Punch *(See page 247.)*

______ **1.** Section A-A is a(n) ________ section.

______ **2.** The section lining symbol indicates ________.

A. cast iron
B. malleable iron
C. general use
D. A, B, and C

______ **3.** The maximum overall diameter of the Holder–Punch is ________″.

______ **4.** All chamfers are cut at a(n) ________° angle.

______ **5.** The minimum overall depth of the Holder–Punch is ________″.

______ **6.** The air hole is ________.

A. ∅3/16
B. drilled thru
C. 30° from vertical
D. A, B, and C

______ **7.** The maximum diameter at A is ________″.

______ **8.** Fillets are specified to have a(n) ________″ radius.

T F **9.** Datum A is perpendicular to datum B within a .00025″ tolerance zone.

T F **10.** The width of the chamfer at B is .06″.

______ **11.** Drawing No. 217203 supercedes and replaces Drawing No. ________.

______ **12.** The distance across flats on the center shaft is ________″.

______ **13.** Eight ∅.62 holes are ________″ deep.

______ **14.** Dimensions of 1.104″ and 1.562″ show the ________ of centerpoints for eight drilled holes.

______ **15.** The diameter at C is ________″.

______ **16.** Four counterbored holes are located ________″ from the centerpoint.

A. .67
B. .875
C. 1.104
D. 1.562

______ **17.** The depth at D is ________″.

______ 18. The depth at F is ________″.

A. 1.795
B. 1.985
C. 2.175
D. 2.72

______ 19. The 2.2010″ diameter at A is ________ to datum B.

______ 20. The depth at E is ________″.

______ 21. The four counterbored holes have a counterbore diameter of ________″.

T F 22. All dimensions are aligned.

______ 23. The cutting plane line for Section A-A is represented by a(n) ________ line.

______ 24. Surface G is parallel to datum A within a(n) ________″ tolerance zone.

______ 25. Datum B has a(n) ________″ diameter under a least material condition.

______ 26. The drawing was completed on ________.

______ 27. The Holder–Punch is to be marked ________.

______ 28. All flat bottom holes are ________″ in diameter.

______ 29. The scale of the drawing is ________.

______ 30. All three-place dimensions have a tolerance of ________″ unless otherwise specified.

______ 31. The four counterbored holes have a counterbore depth of ________″.

T F 32. The Holder–Punch is finished to a 125 microinch finish unless otherwise specified.

T F 33. The part is marked with the part number.

T F 34. The air hole is ∅.20.

T F 35. The part is hardened to RC 60-62.

// .005 A

Trade Test 5

Name ______________________________ Date ______________

Detail, Bottom Die Holder *(See pages 248 and 249.)*

T F **1.** All decimal dimensions are ±.005″ unless otherwise specified.

T F **2.** Item 3 can be machined from a piece of plate steel $4\frac{7}{8}$″ long.

T F **3.** All tapped holes are drilled through.

______ **4.** The drilled hole at A is taper-reamed to a depth of ________″.

______ **5.** The maximum overall length of the Bottom Die Holder is ________″.

A. $12\frac{13}{32}$ C. $12\frac{7}{16}$
B. $12\frac{27}{64}$ D. neither A, B, nor C

______ **6.** The dimension at M is ________″.

______ **7.** The overall height of the Bottom Die Holder is ________″.

T F **8.** Items 2 and 3 are welded together.

T F **9.** Section A-A is taken from the front orthographic view.

T F **10.** The dimension at I is a location dimension.

______ **11.** A total of ________ bronze bushings are required for the assembly.

______ **12.** A(n) ________″ radius is typical for all rounded corners.

T F **13.** The Bottom Die Holder is symmetrical in the top view.

______ **14.** The centerpoints for drilled and tapped holes at D are located ________″ above the base.

A. 3.656 C. 5.156
B. 4.406 D. $5\frac{1}{4}$

______ **15.** The drilled hole at E ________.

A. is located 3.656″ above the base C. both A and B
B. is the centerpoint for the radiused profile D. neither A nor B

______ **16.** The section lining symbol at Section A-A is for ________.

A. cast iron C. general use
B. malleable iron D. A, B, and C

______ **17.** The centerline for the valve is ________″ above the base.

______ **18.** The dimension at F is ________″.

__________ **19.** The thread note at H specifies a(n) ________ thread form.

A. UNC
B. UNF
C. UNEF
D. NPT

__________ **20.** The standard tolerance for fractions, unless otherwise specified, is ________″.

__________ **21.** The minimum distance at J is ________″.

T F **22.** The surface at K is finished.

T F **23.** The bronze bushings are $7/16$″ in length.

T F **24.** The maximum radius of the semi-circular valve seat area is .5625″.

T F **25.** The Bottom Die Holder is drawn at half size.

__________ **26.** The fractional length of L is ________″.

__________ **27.** The overall width of the Bottom Die Holder is ________″.

T F **28.** All counterbores are bored to the same depth.

T F **29.** The plans for the Bottom Die Holder have been revised.

T F **30.** Section A-A is a revolved section.

__________ **31.** The diameter of the counterbore at C is ________″.

__________ **32.** The depth at B is ________″.

__________ **33.** The overall height of Item 2 is ________″.

__________ **34.** The inside diameter of the bronze bushings is ________″.

__________ **35.** The diameter of the hole at G is ________″.

// .005 A

Trade Test 6

Name________________________________ Date ______________

O.D. Grinder *(See pages 250 – 252.)*

______ **1.** A total of ________ separate items are required for the assembly.

T F **2.** Item No. 6 is a purchased item.

T F **3.** Item No. 9 is a manufactured item.

______ **4.** Fractional tolerances, unless otherwise specified, are ±________″.

______ **5.** The drawing number of the assembly is ________.

______ **6.** The bolt at A is a ________.

A. #10-24 UNC
B. ¼-20 UNC
C. 5⁄16-18 UNC
D. ½-20 UNF

______ **7.** The maximum length of the Guide Bar Support is ________″.

______ **8.** The length of the Bearing Plate is ________″.

______ **9.** The part at B is manufactured by ________.

______ **10.** The Adjusting Wheel is made from a purchased ________.

______ **11.** Datum surface X on the Guide Bar must be ________ within a .001″ tolerance zone.

______ **12.** The slot at C is ________″ long.

______ **13.** The bronze bushings are placed in the Bearing Plate so they are ________ to datum X.

T F **14.** Datum X on the Bearing Plate is flat within a .001″ tolerance zone.

T F **15.** All slots are .25 cm wide.

T F **16.** The minimum thickness of the Guide Bar is .22″.

T F **17.** Holes in the Guide Bar are tapped with a ¼-20 UNF 2B THD.

T F **18.** The maximum radius allowed at the end of the Guide Bar is .125″.

______ **19.** Bronze bushings are pressed into holes in the ________.

A. Guide Bar Support
B. Bearing Plate
C. both A and B
D. neither A nor B

__________ 20. The 3″ threaded rod is tightened to the Guide Bar Support with a ________ set screw.

A. slotted headless
B. square head
C. socket head
D. neither A, B, nor C

__________ 21. The minimum dimension at D is ________″.

A. 1.35
B. 1.38
C. 1.385
D. 1.41

__________ 22. The overall height of the Guide Bar Support is ________″.

__________ 23. The overall depth of the Bearing Plate is ________″.

__________ 24. The Guide Bar is hardened to ________.

__________ 25. The flat surfaces on the Guide Bar Support are parallel within a(n) ________″ tolerance zone.

T F 26. The Bearing Plate is symmetrical in the front view.

T F 27. All sharp edges are broken on the Guide Bar Support.

T F 28. The Bearing Plate is manufactured from cold-rolled steel.

T F 29. The shoulder bolt is 3″ long.

__________ 30. The hole in the Adjusting Wheel is ∅________″ before threading.

__________ 31. Surface E on the Guide Bar Support is ________ to datum X.

__________ 32. The .62 DIA hole provides ________″ clearance for the threaded rod.

__________ 33. All geometric tolerances have a(n) ________″ tolerance zone.

__________ 34. The overall height of the Bearing Plate is ________″.

A. .75
B. .87
C. 1.25
D. 2.25

__________ 35. Tapped holes at F are located to within ________″.

//	.005	A

Final Exam

Name ______________________________ Date ______________

3.5 Vise *(See pages 253 – 255.)*

_________ 1. The Vise Screw has a(n) _________ thread.

_________ 2. The Handle Cap has a(n) _________ chamfer on both edges.

_________ 3. The Vise Screw is _________ to within a .001″ tolerance zone.

A. concentric
B. runout
C. cylindrical
D. round

_________ 4. The maximum width of the Pressure Plate is _________″.

A. 1.875
B. 1.8775
C. 1.880
D. 1.885

_________ 5. The shoulder cut in the bottom of the Sliding Jaw is _________″ deep.

T F 6. The Base has an overall width of 3.500″.

T F 7. Datum A is parallel within a .002″ tolerance zone.

T F 8. The Vise Screw is lubricated with oil prior to assembly.

_________ 9. The 3.5 Vise is painted _________ prior to assembly.

A. blue
B. gray
C. red
D. black

_________ 10. All machined surfaces are finished to a(n) _________ finish.

_________ 11. The Vise Screw extends _________″ beyond the Base when fully opened.

_________ 12. To fully use the 3.5 Vise, a space of _________ is required.

A. 7.55″ × 3.50″
B. 8.50″ × 4.50″
C. 10.915″ × 3.50″
D. 11.965″ × 3.50″

_________ 13. The Vise Screw is held in the Sliding Jaw by a(n) _________.

A. slot head set screw
B. Phillips head set screw
C. round head machine screw
D. hex head set screw

_________ 14. The Base is _________ to its finished length.

A. machined
B. cast
C. forged
D. stamped

_________ **15.** The maximum length of the assembled Handle is _________″.

A. 3.355 C. 3.575
B. 3.560 D. 3.590

T F **16.** Datum Z is flat within a .001 tolerance zone.

T F **17.** The minimum distance between centers on the Pressure Plate is .620″.

T F **18.** All threaded holes have a ¼ × 28 UNF thread.

T F **19.** The nominal clearance between the Base and Sliding Jaw is .020″.

_________ **20.** The bottom of the Base is _________ to datum A.

_________ **21.** The Base Jaw Plate is made with _________ steel.

_________ **22.** The handle has a(n) _________ of .004″ with reference to datum axis Y.

_________ **23.** The 3.5 Vise assembly drawing was checked on _________.

_________ **24.** When the Sliding Jaw Plate meets the Base Jaw Plate, they are parallel within a _________″ tolerance zone.

A. .001 C. .005
B. .002 D. .006

T F **25.** All parts are drawn to the same scale.

T F **26.** All fractional dimensions are accurate within a 1/32 tolerance zone.

_________ **27.** Drawings were approved by _________.

A. JDK C. TRL
B. JFP D. GMP

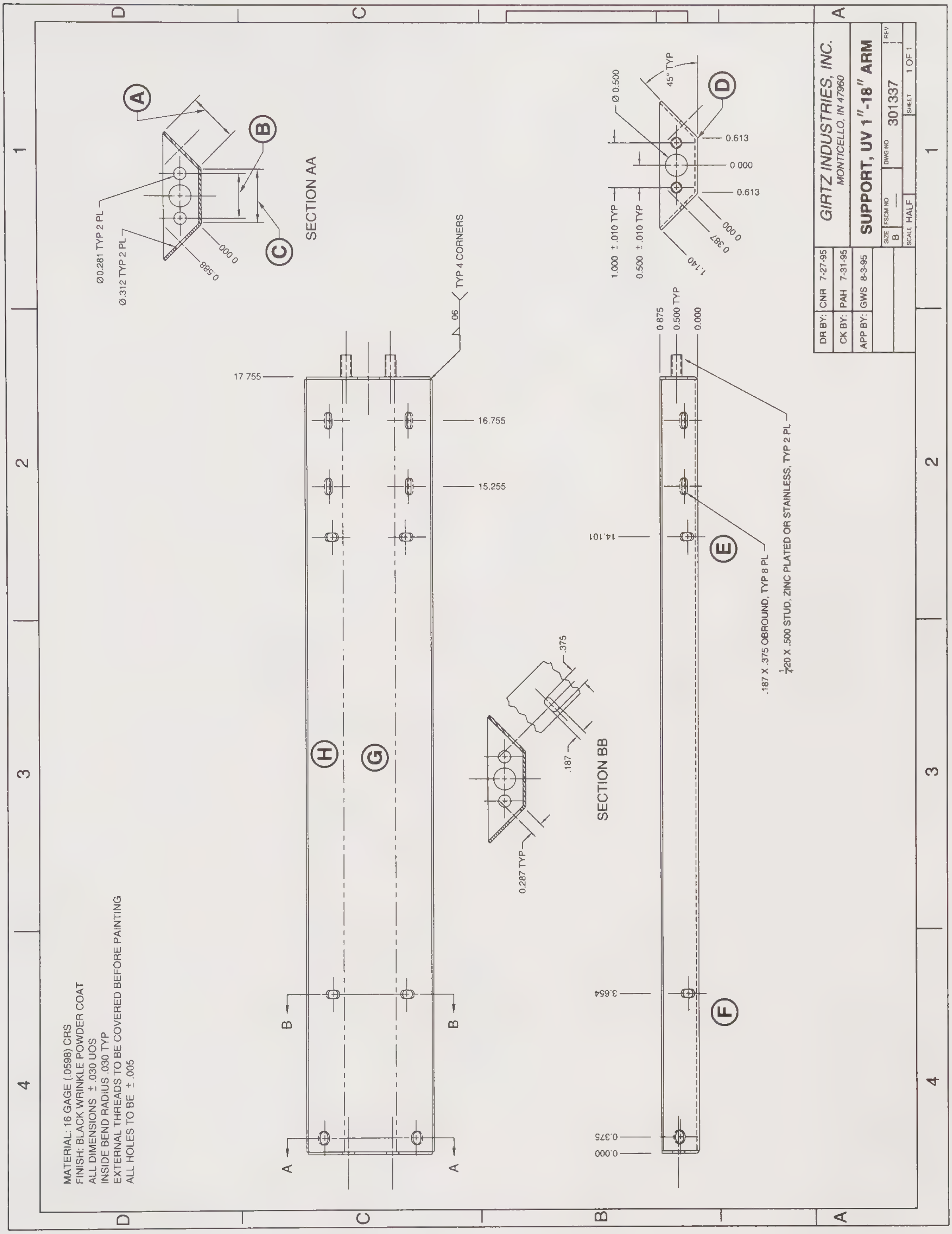
_________ **28.** The 3.5 Vise has a maximum opening of _________″.

A. 3.365 C. 4.415
B. 3.500 D. 7.550

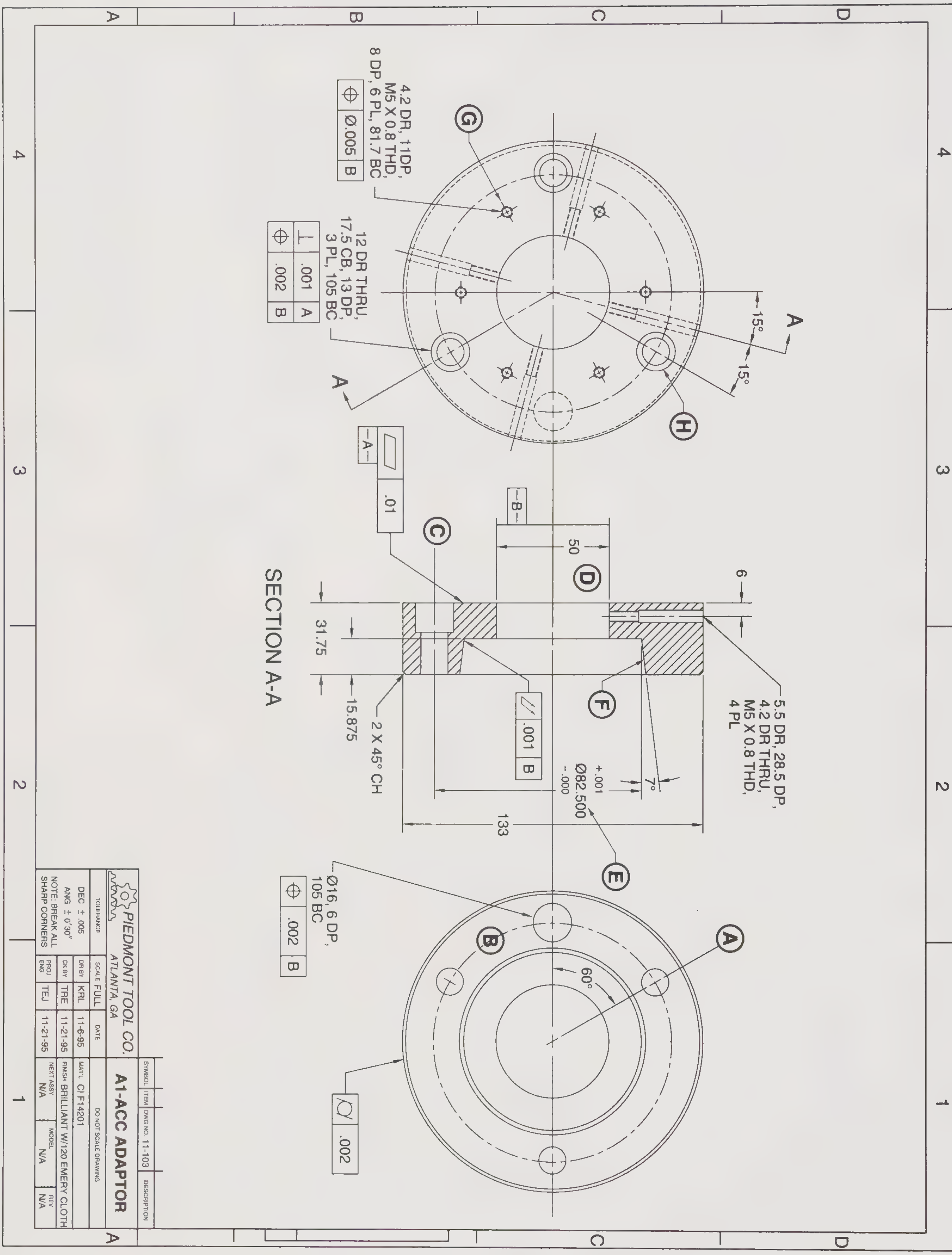
T F **29.** The Handle is made of cold-rolled steel.

_________ **30.** All sizes on the cast parts that are not machined later are given as _________ dimensions.

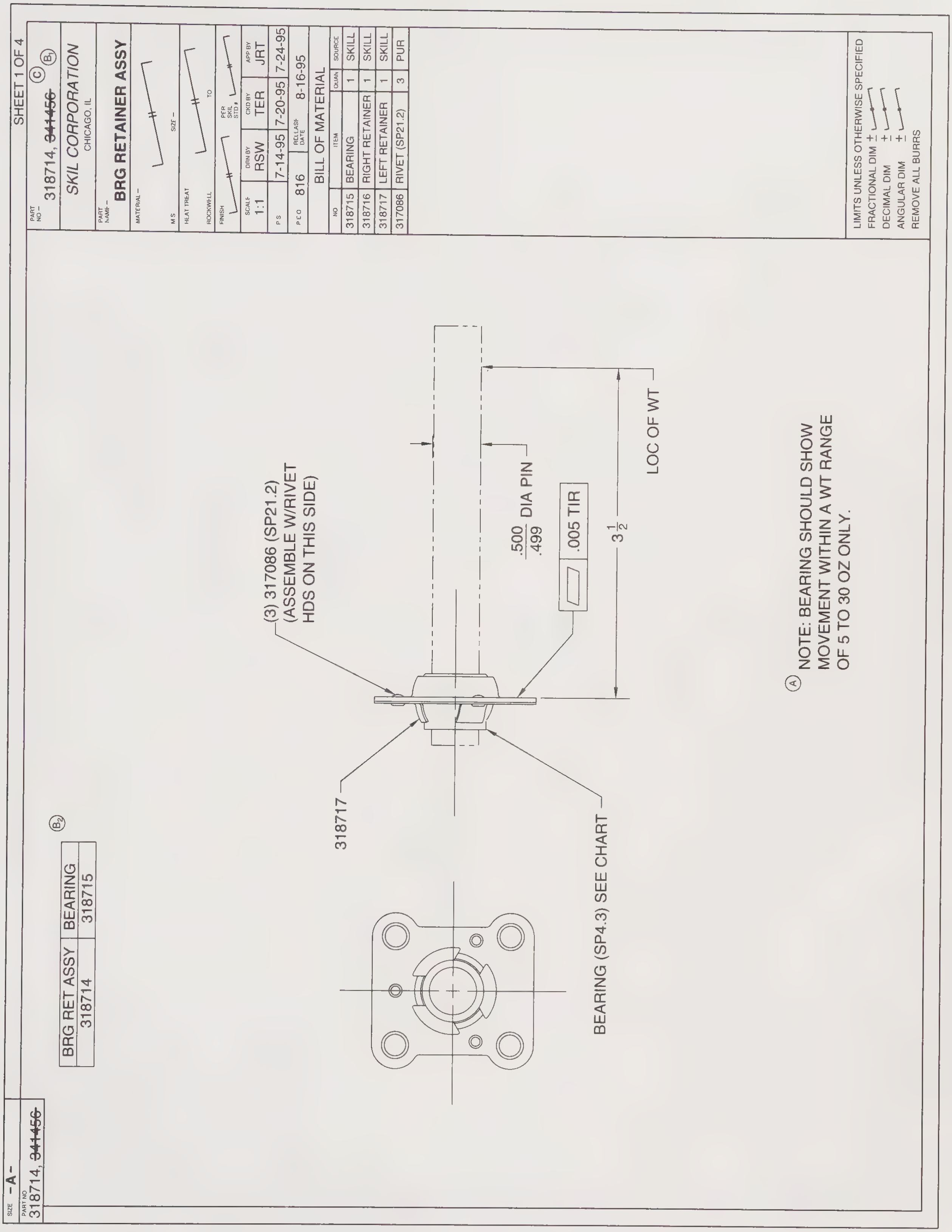
A. reference C. nominal
B. basic D. missing



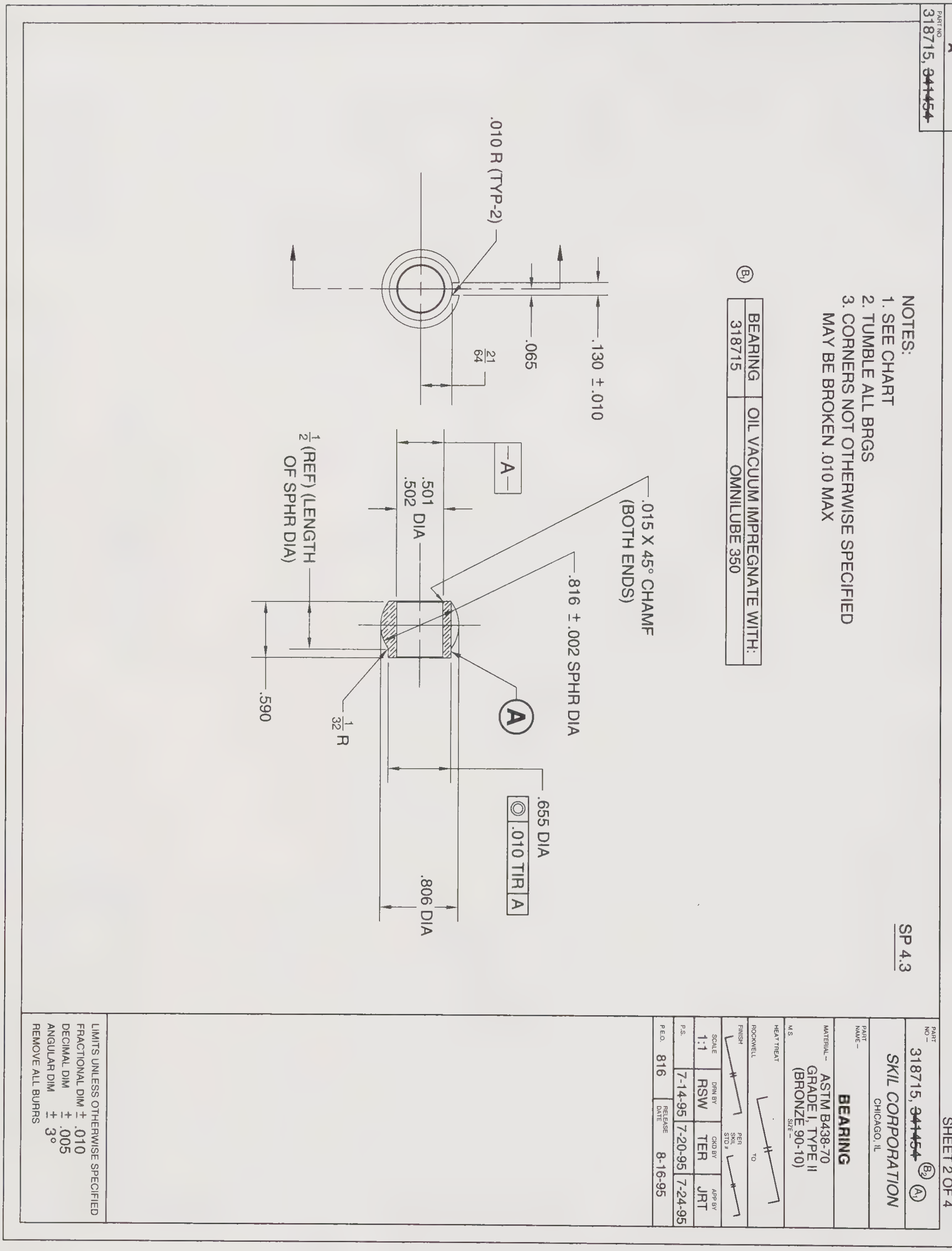
SUPPORT, UV 1″–18″ ARM



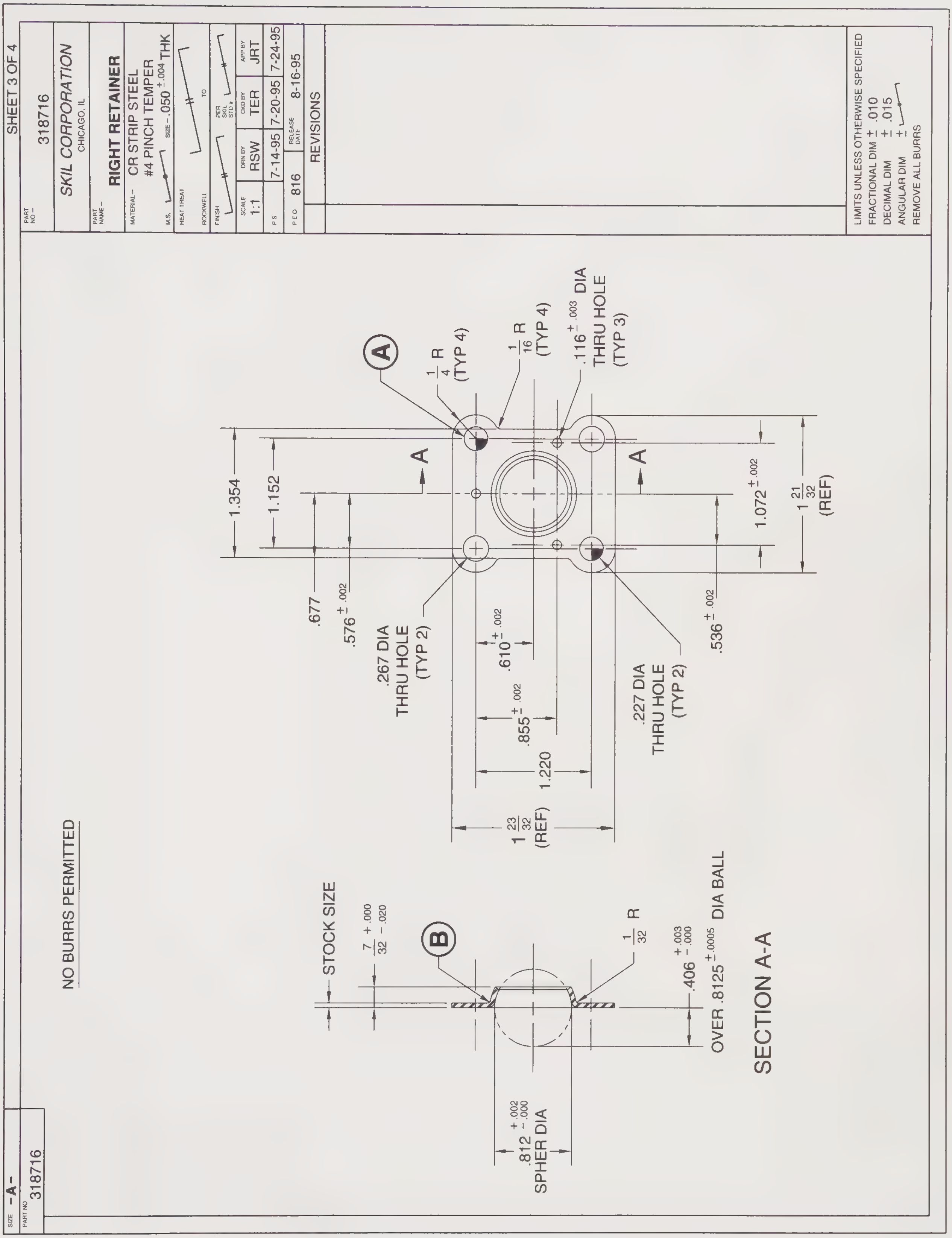
A1-ACC ADAPTOR



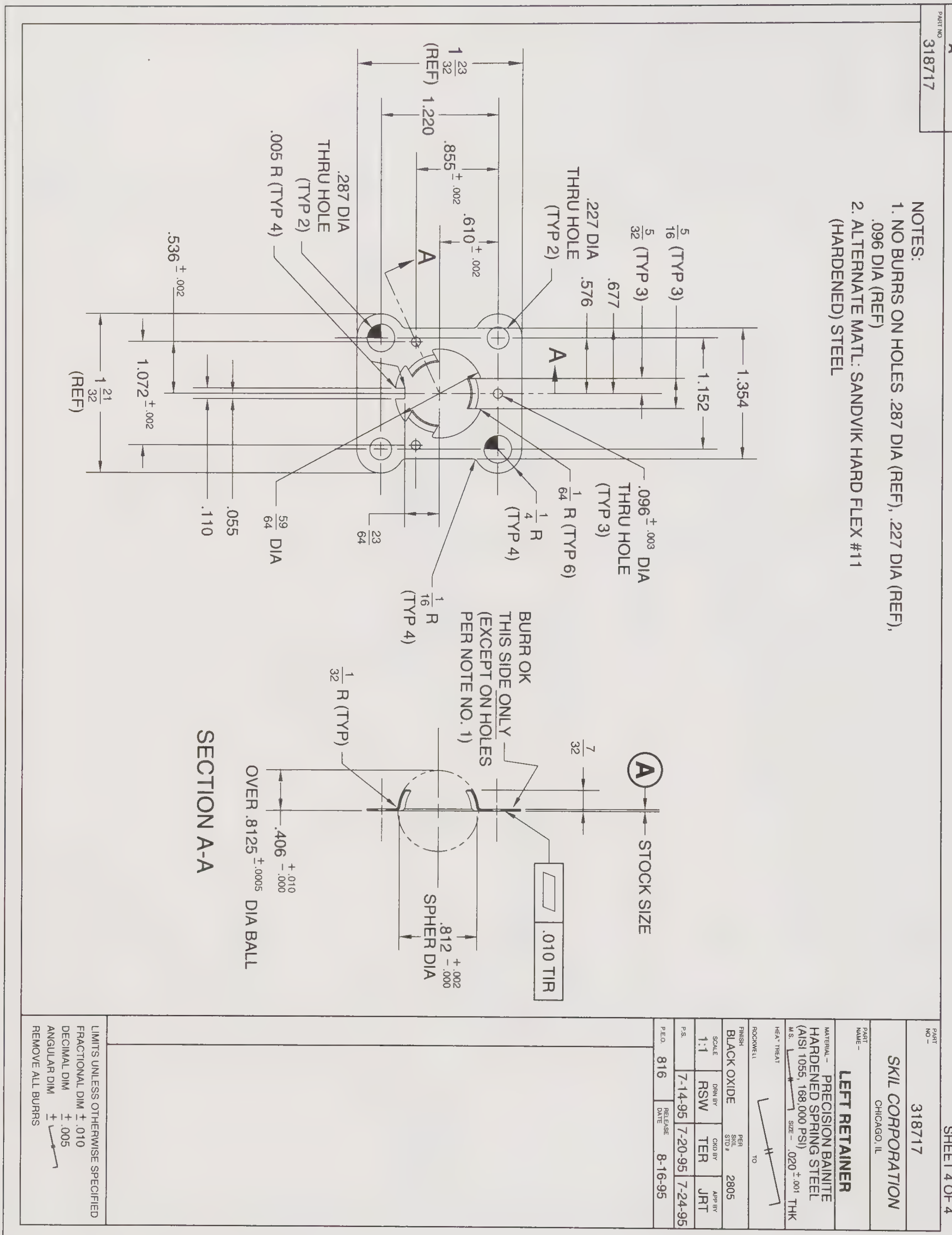
BEARING RETAINER ASSEMBLY



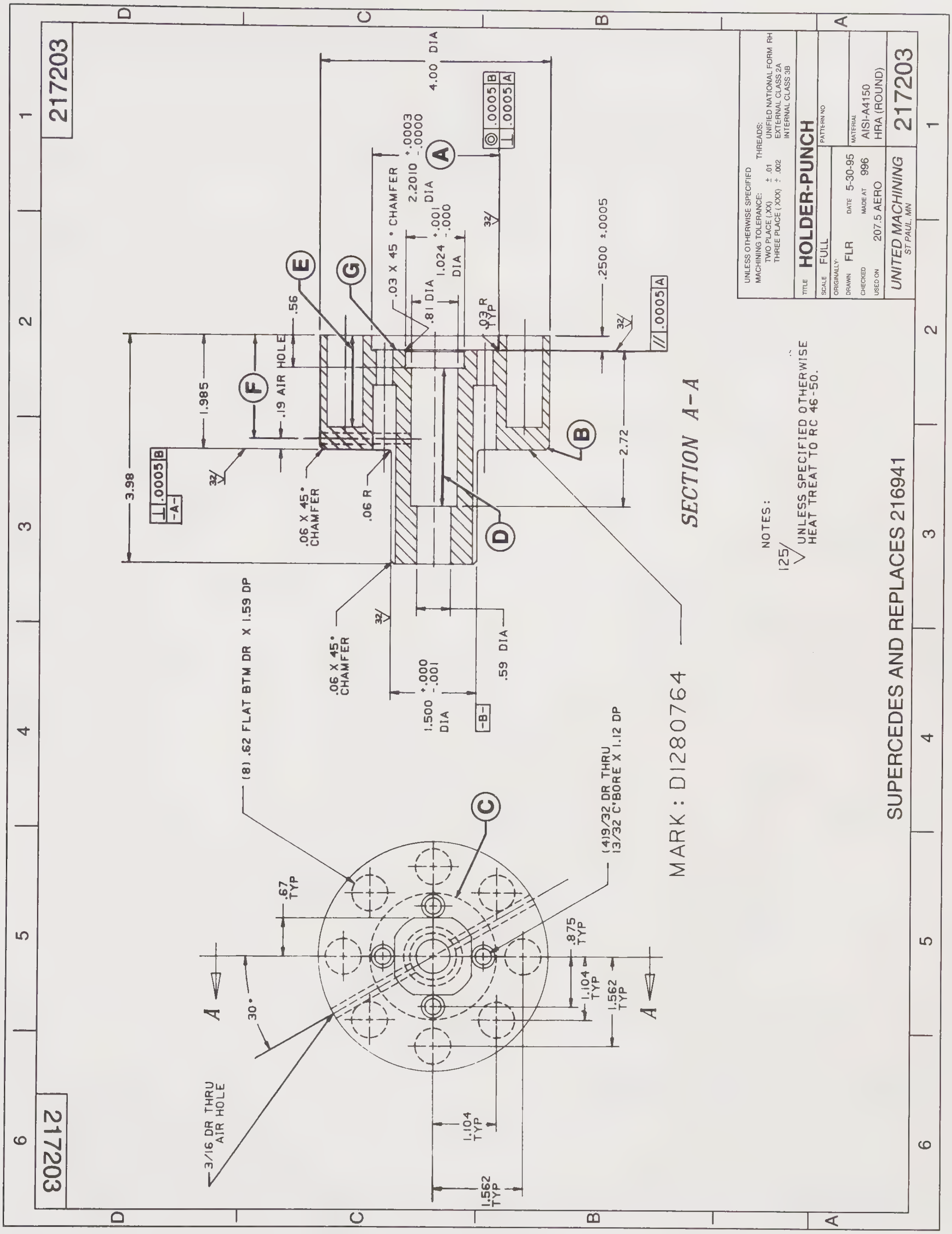
BEARING RETAINER ASSEMBLY



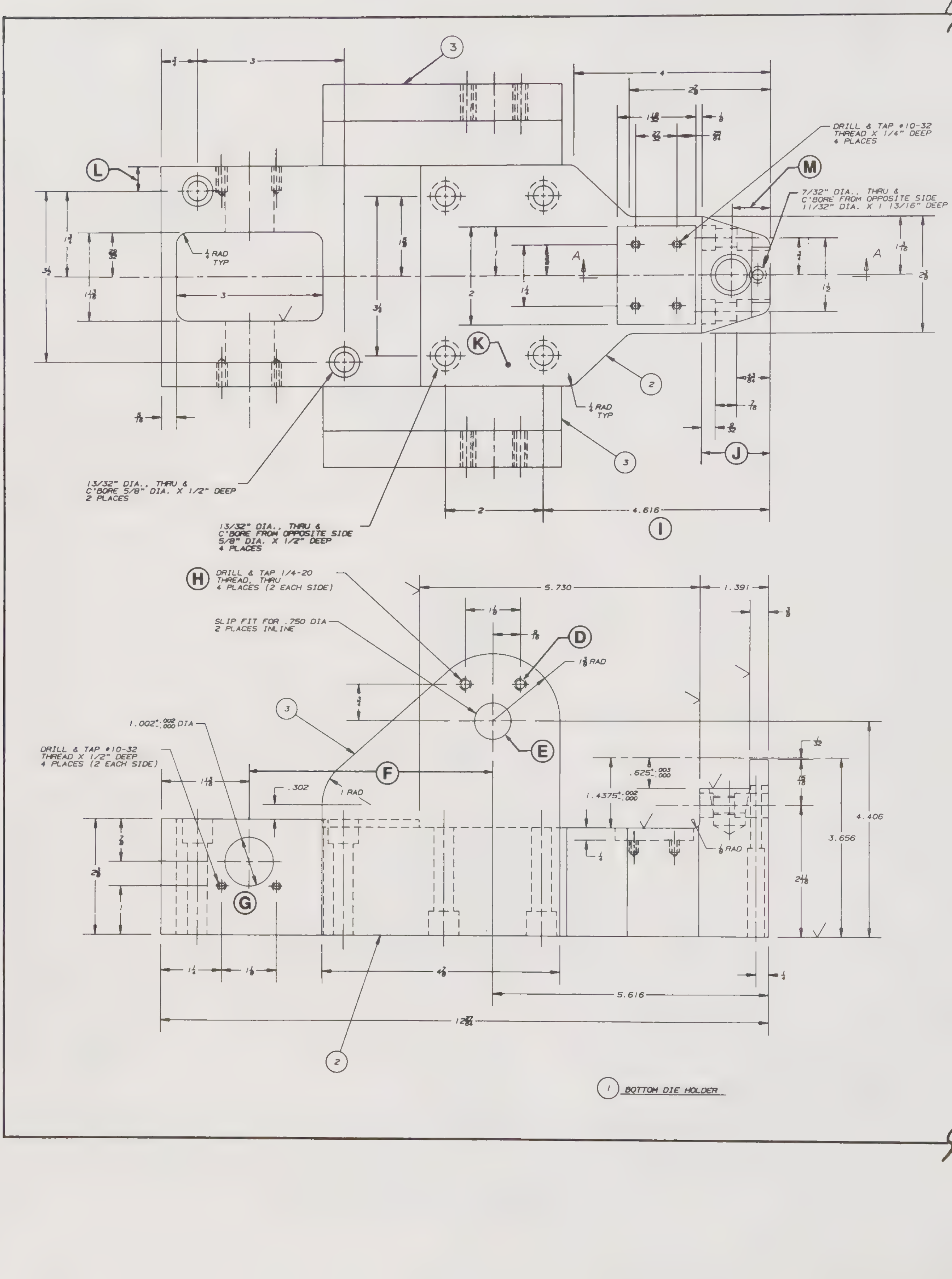
BEARING RETAINER ASSEMBLY



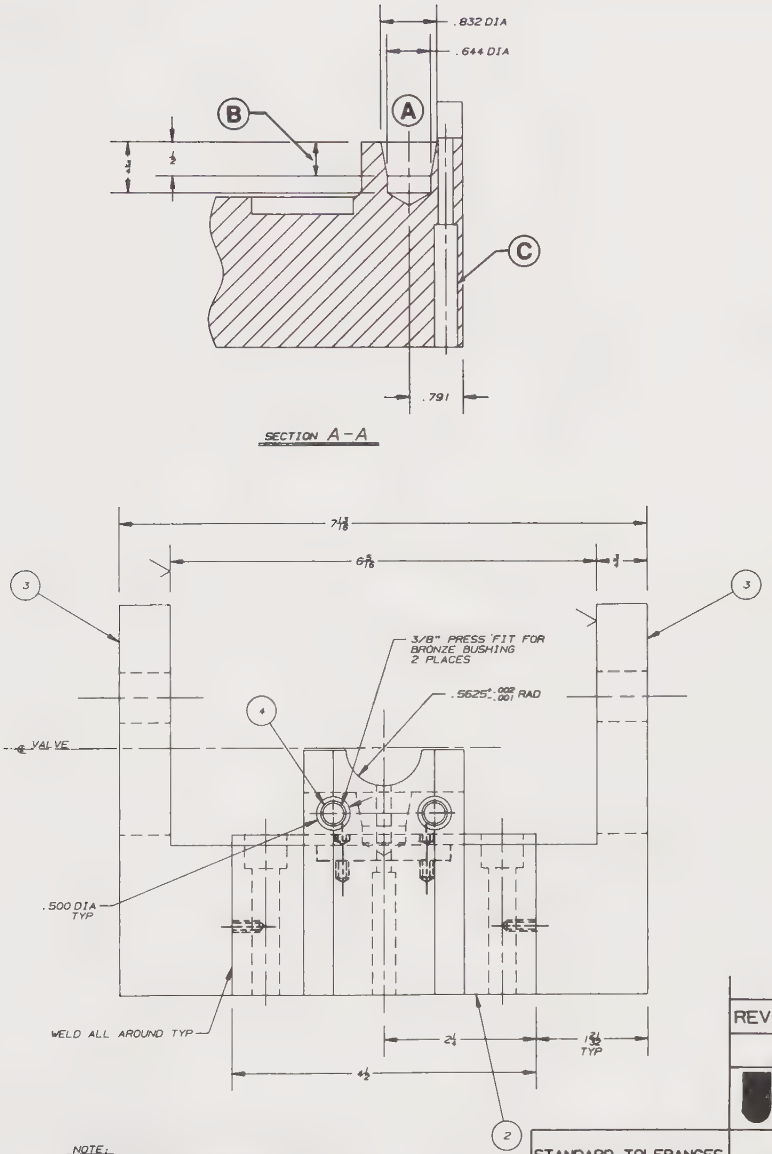
BEARING RETAINER ASSEMBLY



HOLDER–PUNCH


DRILL & TAP #10-32
THREAD X 1/4" DEEP
4 PLACES
7/32" DIA., THRU &
C'BORE FROM OPPOSITE SIDE
11/32" DIA. X 1 13/16" DEEP
13/32" DIA., THRU &
C'BORE 5/8" DIA. X 1/2" DEEP
2 PLACES
13/32" DIA., THRU &
C'BORE FROM OPPOSITE SIDE
5/8" DIA. X 1/2" DEEP
4 PLACES
DRILL & TAP 1/4-20
THREAD, THRU
4 PLACES (2 EACH SIDE)
SLIP FIT FOR .750 DIA
2 PLACES INLINE
DRILL & TAP #10-32
THREAD X 1/2" DEEP
4 PLACES (2 EACH SIDE)
1 BOTTOM DIE HOLDER
4.616
5.730
1.391
5.616
4.406
3.656
.302
1 RAD
TYP
A
L
M
K
J
I
H
D
E
F
G

BILL OF MATERIAL			
ITEM	MATERIAL	QTY.	DESCRIPTION
1	-	1	BOTTOM DIE HOLDER
2	4140	1	PLATE 3 3/4" X 4 1/2" X 12 7/16" LG.
3	4140	2	PLATE 1 21/32" X 4 7/8" X 5 13/16" LG.
4	-	2	BRONZE BUSHING 3/8" O.D. X 5/16" I.D. X 7/16" LG.



NOTE:
ALL DECIMAL DIMENSIONS ARE ±.001
UNLESS OTHERWISE SPECIFIED.

REV	DATE	BY	DESCRIPTION

REVISIONS

WORTHINGTON INDUSTRIES
1205 DEARBORN DR. , COLUMBUS OHIO

DETAIL, BOTTOM DIE HOLDER
360 CRIMP SCISSORS TYPE
NON-REFILLABLE VALVE

STANDARD TOLERANCES
FRACTION: ±1/64
DECIMAL : ±.005
ANGLES : ±1/2
UNLESS OTHERWISE SPECIFIED

DATE: 9/28/95 | DRN. BY: MATY | SCALE: 1"=1"
SHEET 1 OF 1 | DWG. NO.: D-ED-02-616-D0014

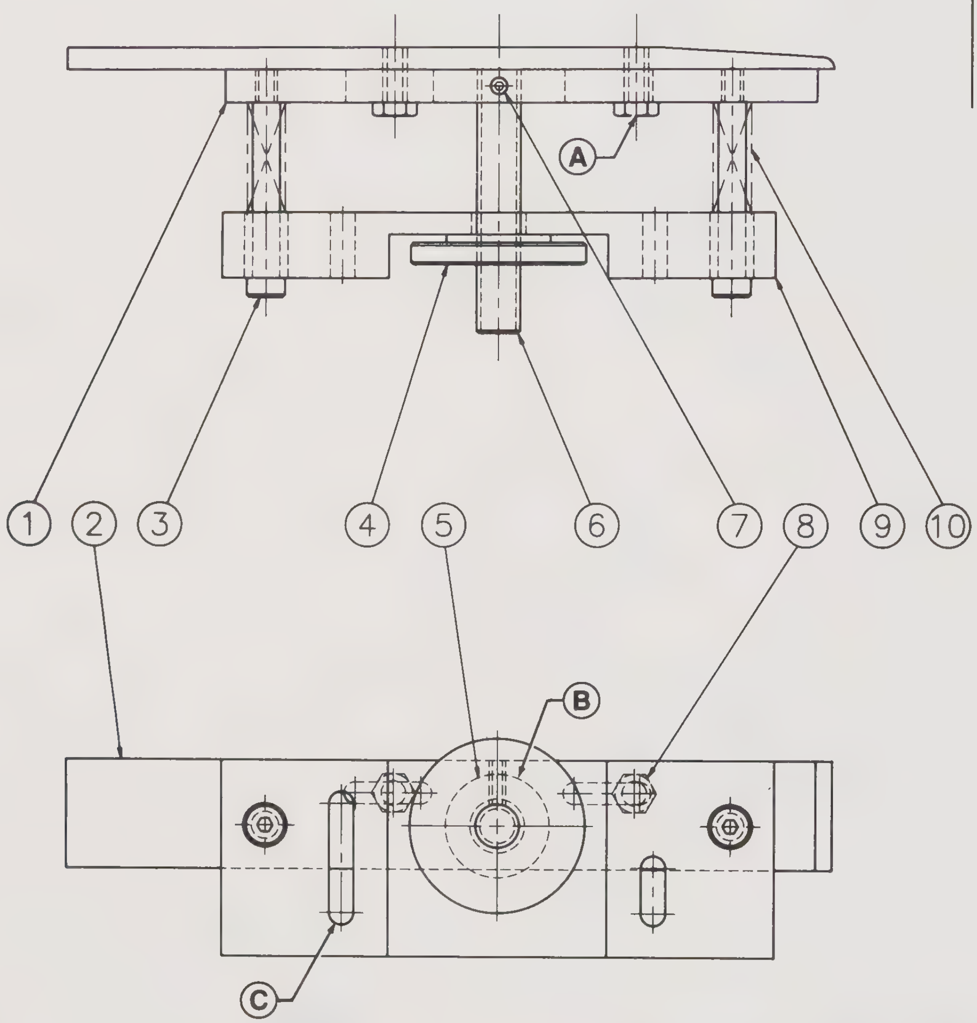
DETAIL, BOTTOM DIE HOLDER

ITEM NO.	QTY.	DESCRIPTION
1	1	GUIDE BAR SUPPORT B-803-28201
2	1	GUIDE BAR B-803-28200
3	2	5/16 DIA. X 2" LG. SHOULDER BOLT
4	1	ADJUSTING WHEEL B-803-28203
5	1	THRUST BEARING #TB1019 BOSTON GEAR CO.
6	1	1/2-20 UNF X 3" LG. THREADED ROD
7	1	#10-24 UNC X 3/8 LG. CUP PT. SOC HD. SET SCR.
8	2	1/4-20 UNC X 1/2 LG. HEX HD. SCR.
9	1	BEARING PLATE B-803-28202
10	2	SPRING (.360 O.D./.032 DIA. MUSIC WIRE (PLATED)/2" LG.)

DRAWING NUMBER C-803-28199

SHTS. SHT.

CHANGES

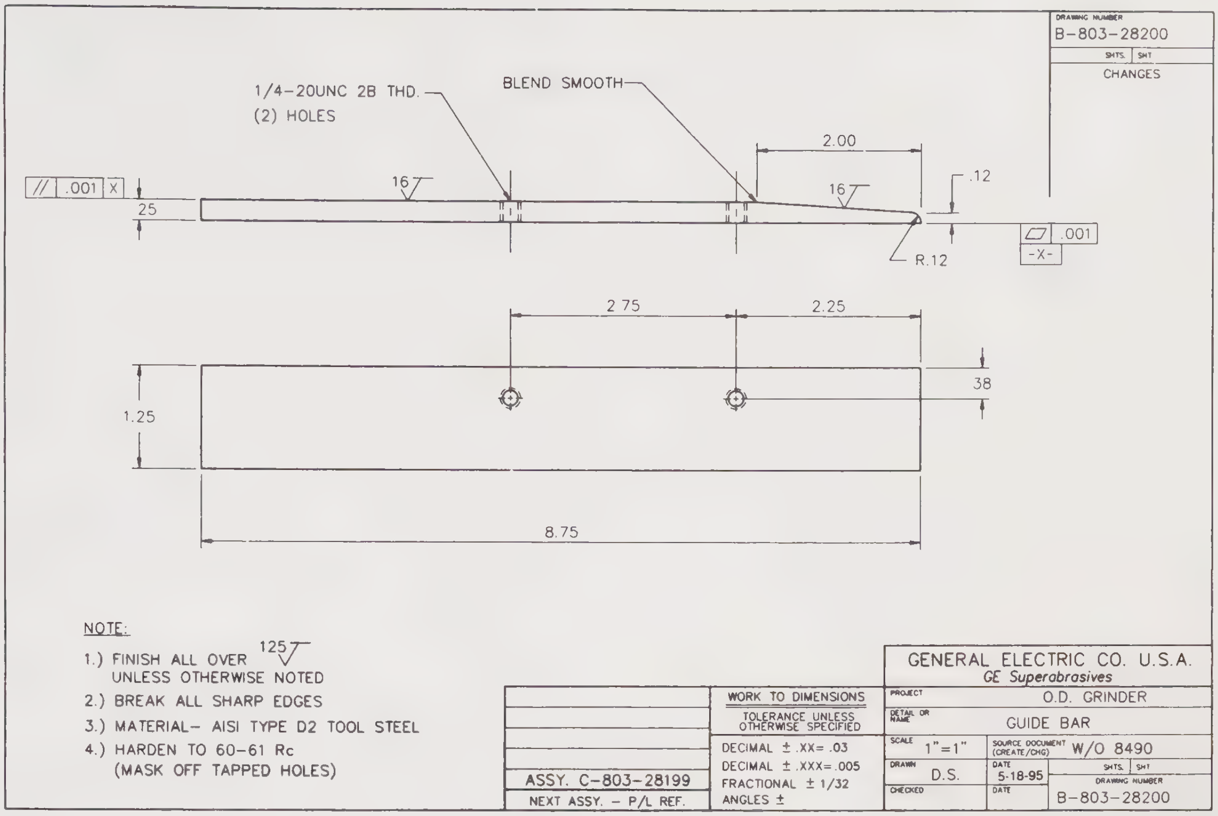


WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
DECIMAL ± .XX=
DECIMAL ± .XXX=
FRACTIONAL ± 1/32
ANGLES ±

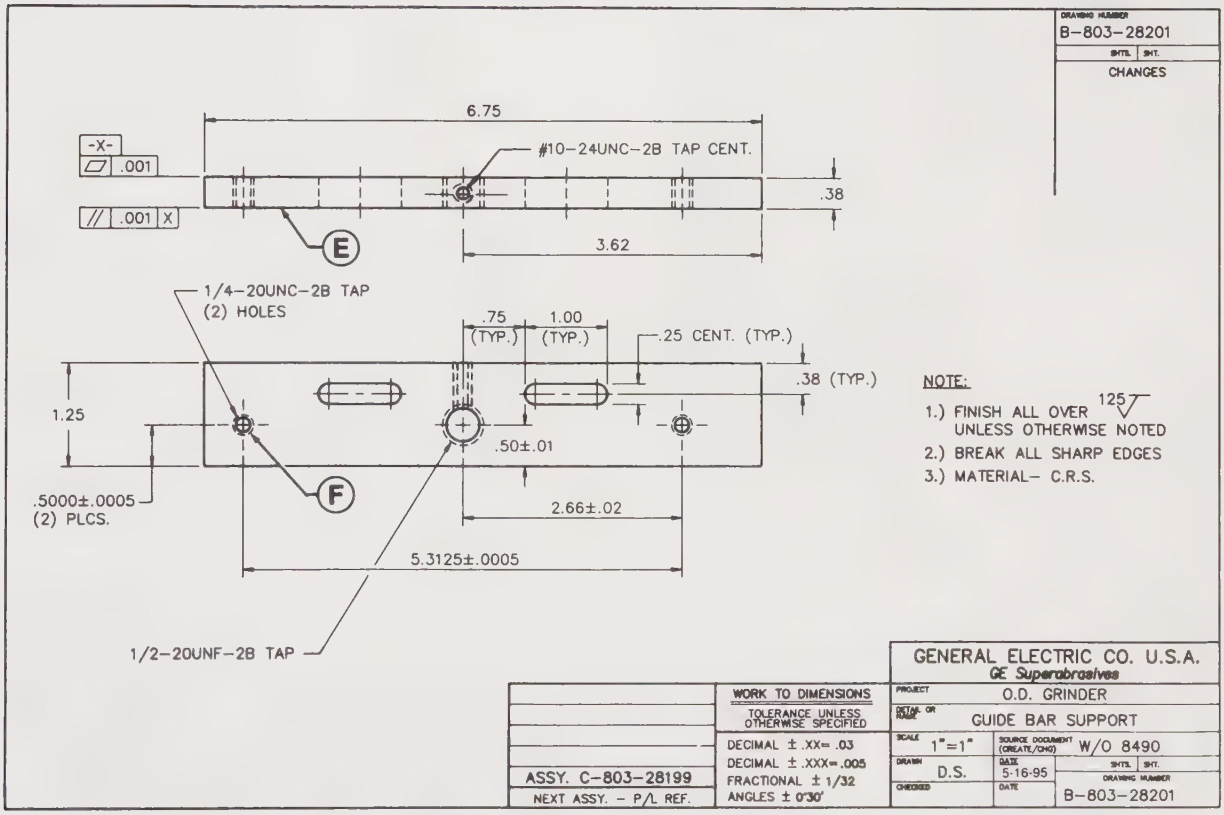
NEXT ASSY. – P/L REF.

GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
PROJECT O.D. GRINDER
DETAIL OR NAME FRONT GRINDING GUIDE ASSY.
SCALE 1"=1"
SOURCE DOCUMENT (CREATE/CHG) W/O 8490
DRAWN D.S.
DATE 5-22-95
SHTS. SHT.
CHECKED
DATE
DRAWING NUMBER C-803-28199

O.D. GRINDER

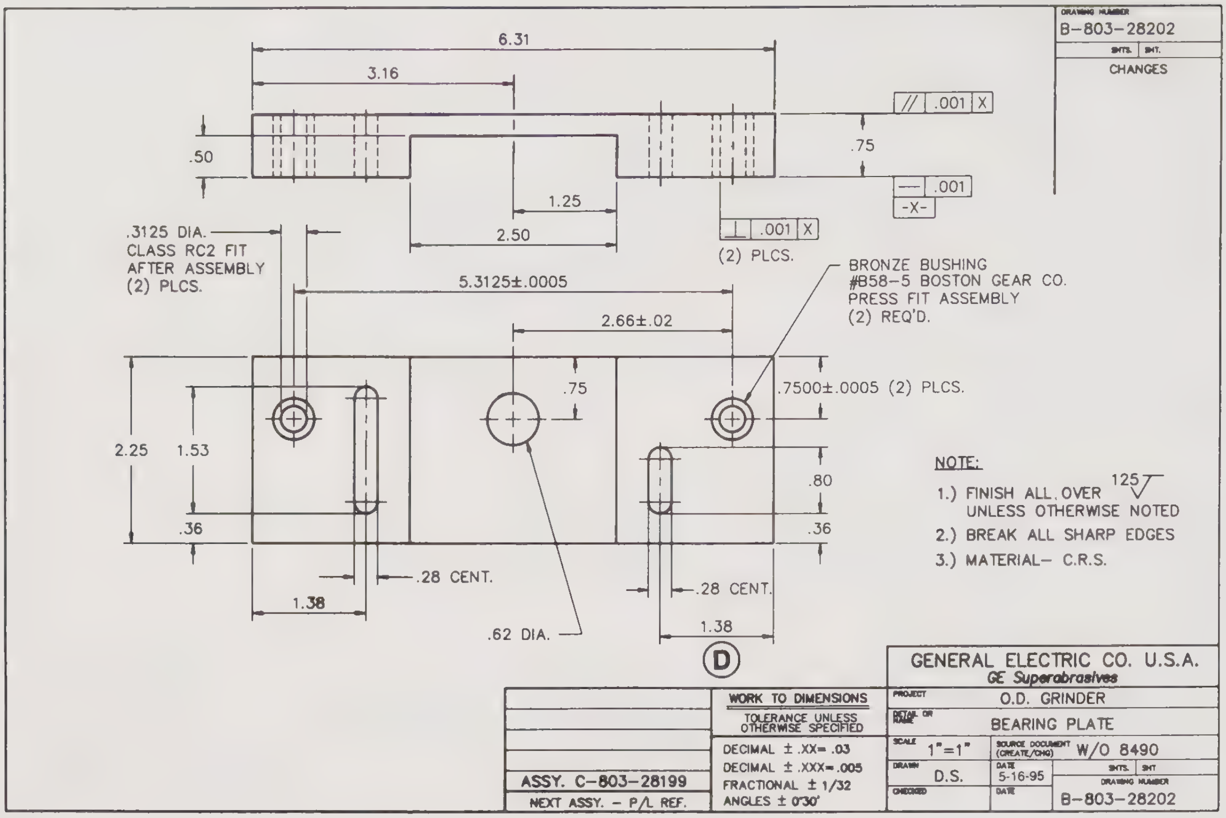


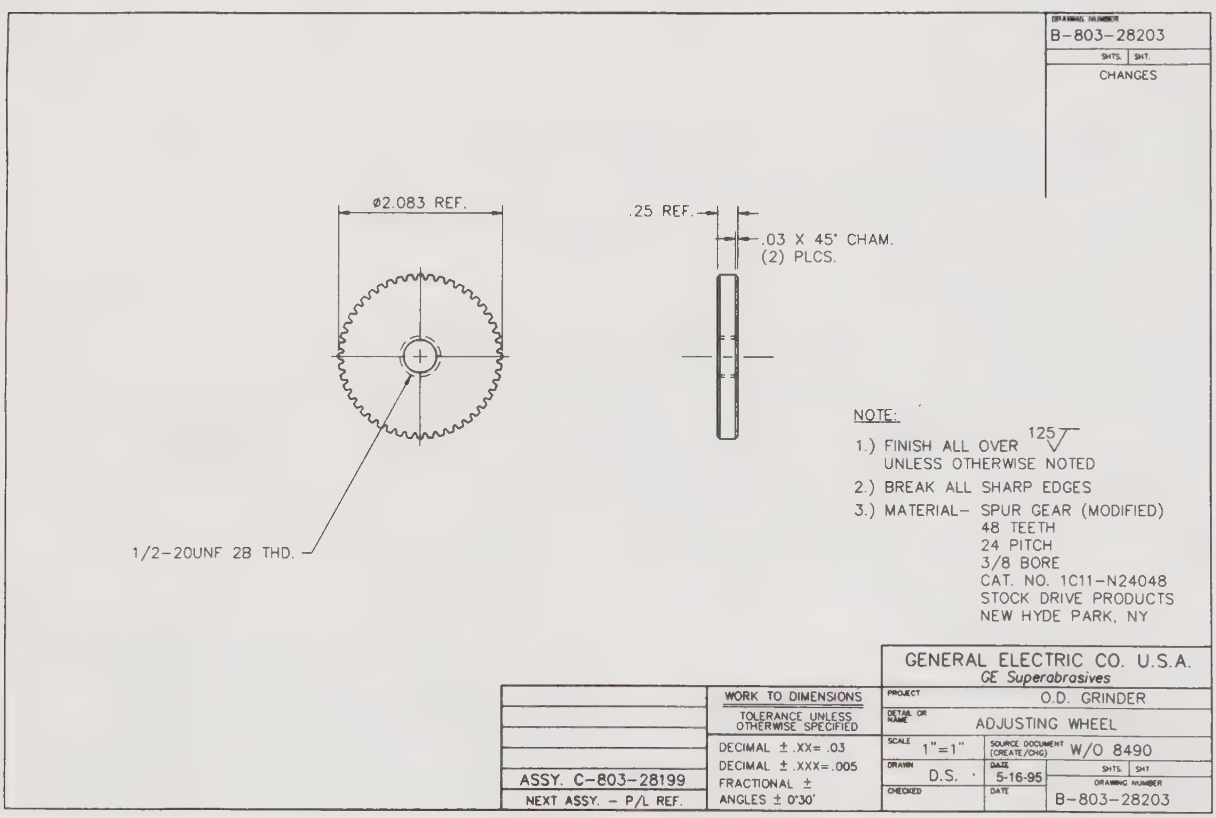
DRAWING NUMBER
B-803-28200
SHTS. SHT
CHANGES
1/4-20UNC 2B THD.
(2) HOLES
BLEND SMOOTH
2.00
.12
16
.001 X
25
.001
-X-
R.12
2.75
2.25
38
1.25
8.75
NOTE:
1.) FINISH ALL OVER 125 UNLESS OTHERWISE NOTED
2.) BREAK ALL SHARP EDGES
3.) MATERIAL- AISI TYPE D2 TOOL STEEL
4.) HARDEN TO 60-61 Rc (MASK OFF TAPPED HOLES)
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
PROJECT
O.D. GRINDER
DETAIL OR NAME
GUIDE BAR
DECIMAL ± .XX= .03
DECIMAL ± .XXX= .005
FRACTIONAL ± 1/32
ANGLES ±
SCALE 1"=1"
SOURCE DOCUMENT (CREATE/CHG) W/O 8490
DRAWN D.S.
DATE 5-18-95
CHECKED
DATE
DRAWING NUMBER B-803-28200
ASSY. C-803-28199
NEXT ASSY. - P/L REF.



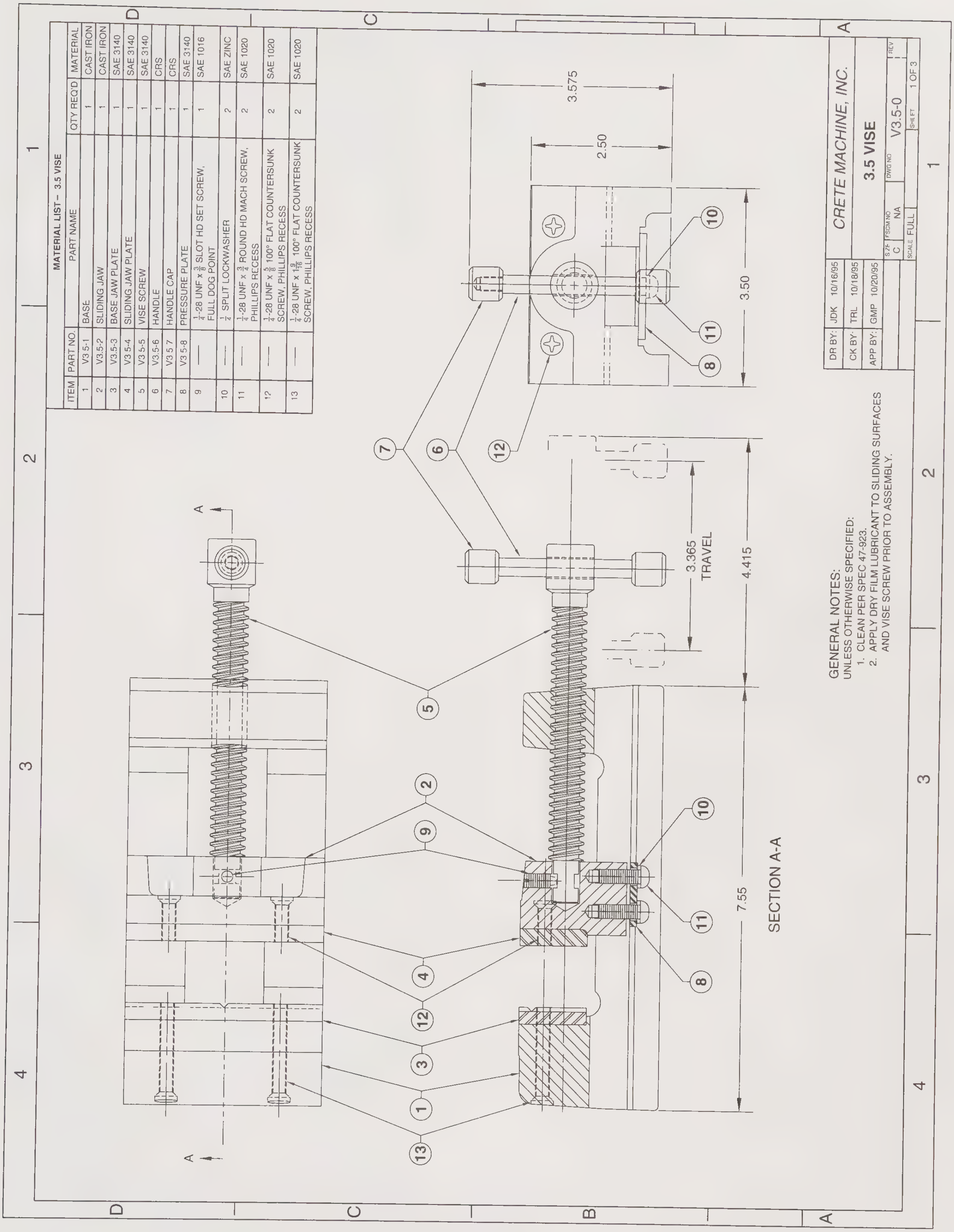
DRAWING NUMBER
B-803-28201
SHTS. SHT.
CHANGES
6.75
-X-
.001
#10-24UNC-2B TAP CENT.
.38
.001 X
E
3.62
1/4-20UNC-2B TAP
(2) HOLES
.75 (TYP.)
1.00 (TYP.)
.25 CENT. (TYP.)
.38 (TYP.)
1.25
.50±.01
F
.5000±.0005
(2) PLCS.
2.66±.02
5.3125±.0005
1/2-20UNF-2B TAP
NOTE:
1.) FINISH ALL OVER 125 UNLESS OTHERWISE NOTED
2.) BREAK ALL SHARP EDGES
3.) MATERIAL- C.R.S.
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
PROJECT
O.D. GRINDER
DETAIL OR NAME
GUIDE BAR SUPPORT
DECIMAL ± .XX= .03
DECIMAL ± .XXX= .005
FRACTIONAL ± 1/32
ANGLES ± 0°30'
SCALE 1"=1"
SOURCE DOCUMENT (CREATE/CHG) W/O 8490
DRAWN D.S.
DATE 5-16-95
CHECKED
DATE
DRAWING NUMBER B-803-28201
ASSY. C-803-28199
NEXT ASSY. - P/L REF.

O.D. GRINDER

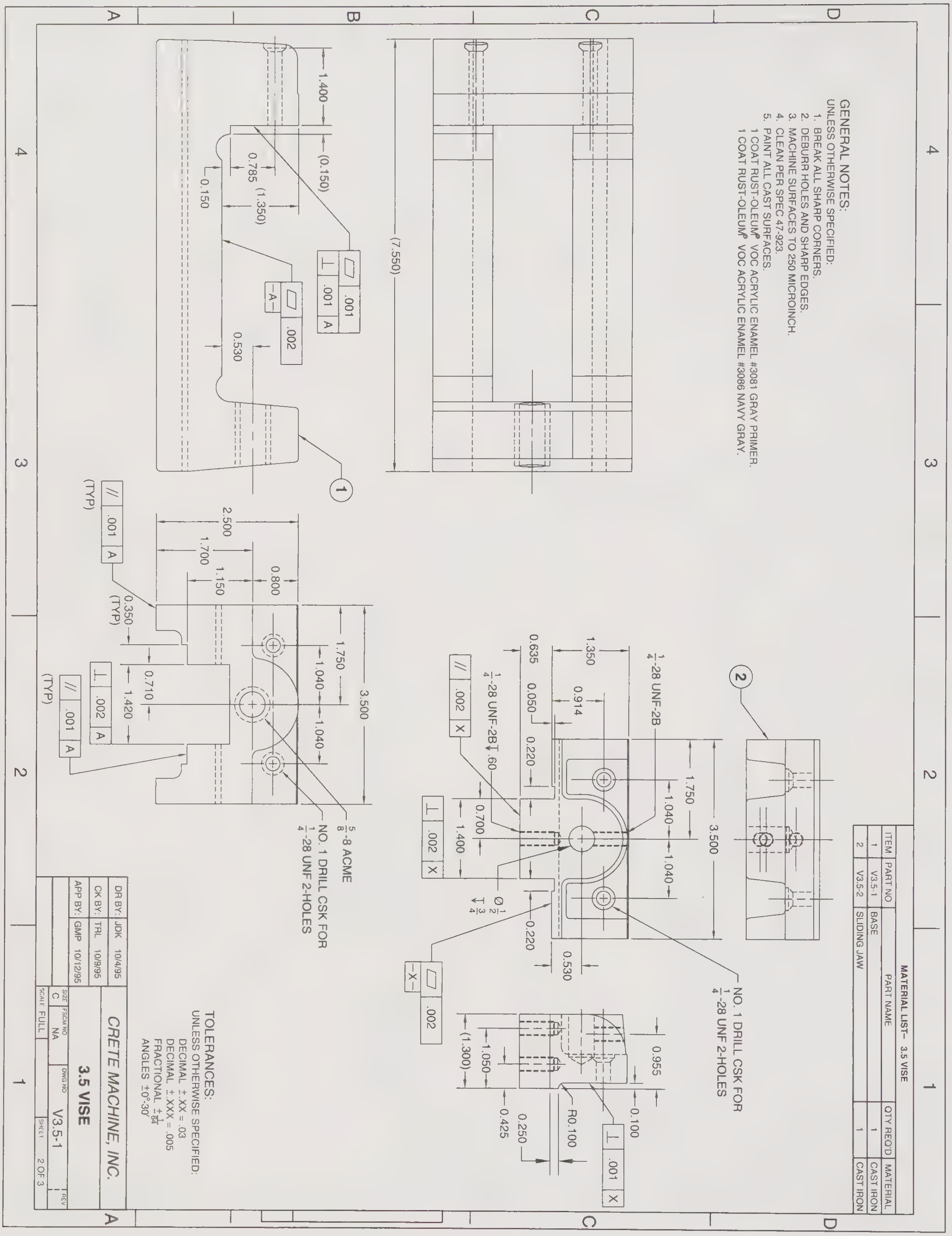

B-803-28202
CHANGES
6.31
3.16
.50
.75
.001 X
.001
-X-
1.25
2.50
.001 X
(2) PLCS.
.3125 DIA.
CLASS RC2 FIT
AFTER ASSEMBLY
(2) PLCS.
5.3125±.0005
BRONZE BUSHING
#B58-5 BOSTON GEAR CO.
PRESS FIT ASSEMBLY
(2) REQ'D.
2.66±.02
.75
.7500±.0005 (2) PLCS.
2.25
1.53
.80
.36
.36
NOTE:
1.) FINISH ALL OVER 125
UNLESS OTHERWISE NOTED
2.) BREAK ALL SHARP EDGES
3.) MATERIAL– C.R.S.
.28 CENT.
.28 CENT.
1.38
1.38
.62 DIA.
D
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
DECIMAL ± .XX= .03
DECIMAL ± .XXX= .005
FRACTIONAL ± 1/32
ANGLES ± 0°30'
ASSY. C-803-28199
NEXT ASSY. – P/L REF.
PROJECT O.D. GRINDER
DETAIL OR NAME BEARING PLATE
SCALE 1"=1"
SOURCE DOCUMENT (CREATE/CHG) W/O 8490
DRAWN D.S.
DATE 5-16-95
CHECKED
DATE
DRAWING NUMBER B-803-28202


B-803-28203
CHANGES
ø2.083 REF.
.25 REF.
.03 X 45° CHAM.
(2) PLCS.
NOTE:
1.) FINISH ALL OVER 125
UNLESS OTHERWISE NOTED
2.) BREAK ALL SHARP EDGES
3.) MATERIAL– SPUR GEAR (MODIFIED)
48 TEETH
24 PITCH
3/8 BORE
CAT. NO. 1C11–N24048
STOCK DRIVE PRODUCTS
NEW HYDE PARK, NY
1/2–20UNF 2B THD.
GENERAL ELECTRIC CO. U.S.A.
GE Superabrasives
WORK TO DIMENSIONS
TOLERANCE UNLESS OTHERWISE SPECIFIED
DECIMAL ± .XX= .03
DECIMAL ± .XXX= .005
FRACTIONAL ±
ANGLES ± 0°30'
ASSY. C-803-28199
NEXT ASSY. – P/L REF.
PROJECT O.D. GRINDER
DETAIL OR NAME ADJUSTING WHEEL
SCALE 1"=1"
SOURCE DOCUMENT (CREATE/CHG) W/O 8490
DRAWN D.S.
DATE 5-16-95
CHECKED
DATE
DRAWING NUMBER B-803-28203

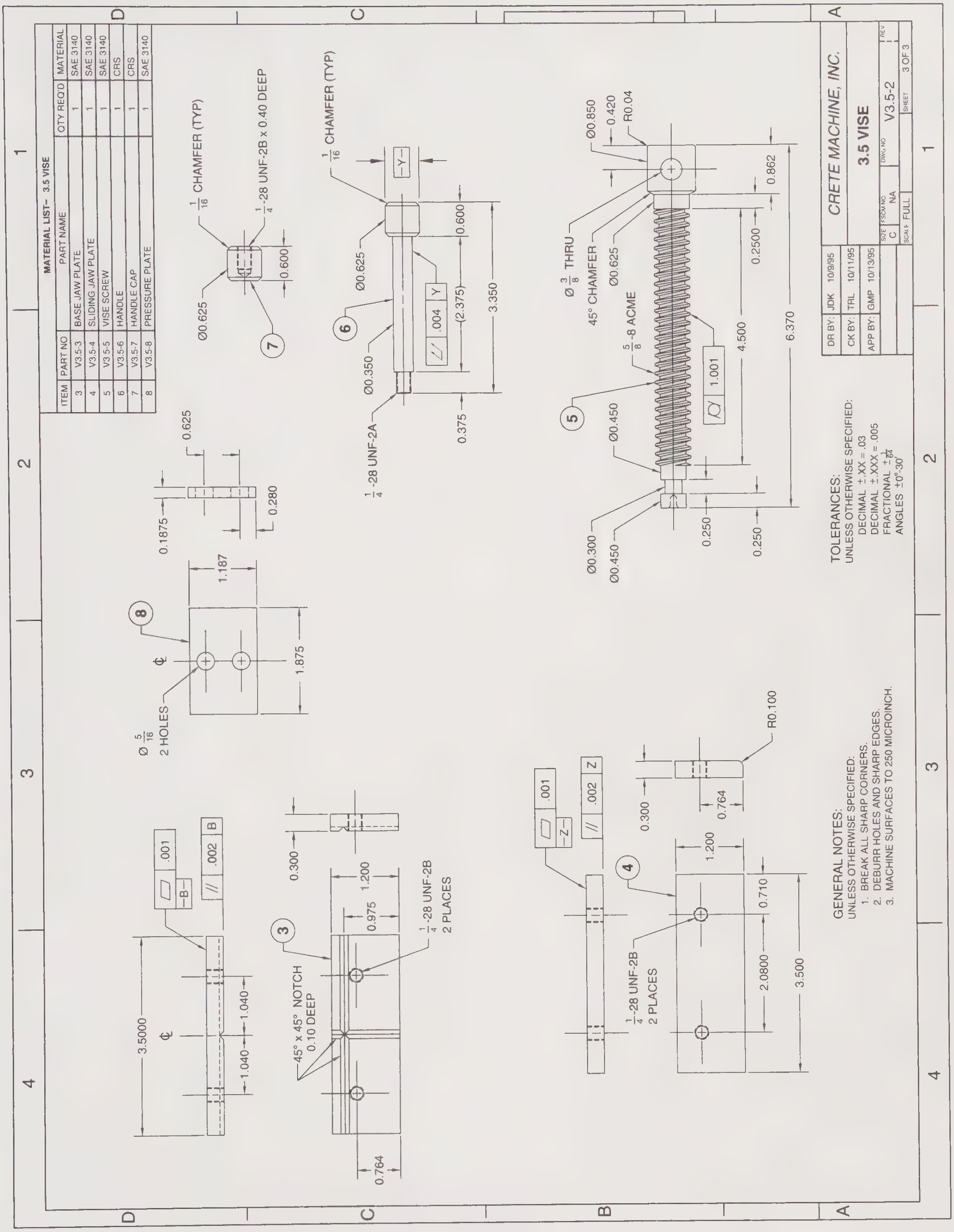
O.D. GRINDER


MATERIAL LIST – 3.5 VISE
ITEM | PART NO. | PART NAME | QTY REQ'D | MATERIAL
1 | V3.5-1 | BASE | 1 | CAST IRON
2 | V3.5-2 | SLIDING JAW | 1 | CAST IRON
3 | V3.5-3 | BASE JAW PLATE | 1 | SAE 3140
4 | V3.5-4 | SLIDING JAW PLATE | 1 | SAE 3140
5 | V3.5-5 | VISE SCREW | 1 | SAE 3140
6 | V3.5-6 | HANDLE | 1 | CRS
7 | V3.5-7 | HANDLE CAP | 1 | CRS
8 | V3.5-8 | PRESSURE PLATE | 1 | SAE 3140
9 | — | 1/4-28 UNF x 3/8 SLOT HD SET SCREW, FULL DOG POINT | 1 | SAE 1016
10 | — | 1/4 SPLIT LOCKWASHER | 2 | SAE ZINC
11 | — | 1/4-28 UNF x 3/4 ROUND HD MACH SCREW, PHILLIPS RECESS | 2 | SAE 1020
12 | — | 1/4-28 UNF x 5/8 100° FLAT COUNTERSUNK SCREW, PHILLIPS RECESS | 2 | SAE 1020
13 | — | 1/4-28 UNF x 1 9/16 100° FLAT COUNTERSUNK SCREW, PHILLIPS RECESS | 2 | SAE 1020
3.575
2.50
3.50
3.365
TRAVEL
4.415
7.55
SECTION A-A
GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED:
1. CLEAN PER SPEC 47-923.
2. APPLY DRY FILM LUBRICANT TO SLIDING SURFACES AND VISE SCREW PRIOR TO ASSEMBLY.
DR BY: JDK 10/16/95
CK BY: TRL 10/18/95
APP BY: GMP 10/20/95
CRETE MACHINE, INC.
3.5 VISE
SIZE C
FSCM NO NA
DWG NO V3.5-0
REV
SCALE FULL
SHEET 1 OF 3

3.5 VISE


GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP CORNERS.
2. DEBURR HOLES AND SHARP EDGES.
3. MACHINE SURFACES TO 250 MICROINCH.
4. CLEAN PER SPEC 47-923.
5. PAINT ALL CAST SURFACES.
1 COAT RUST-OLEUM® VOC ACRYLIC ENAMEL #3081 GRAY PRIMER.
1 COAT RUST-OLEUM® VOC ACRYLIC ENAMEL #3086 NAVY GRAY.
MATERIAL LIST– 3.5 VISE
ITEM | PART NO | PART NAME | QTY REQ'D | MATERIAL
1 | V3.5-1 | BASE | 1 | CAST IRON
2 | V3.5-2 | SLIDING JAW | 1 | CAST IRON
NO. 1 DRILL CSK FOR 1/4-28 UNF 2-HOLES
1/4-28 UNF-2B
1/4-28 UNF-2B ↧ .60
5/8-8 ACME
TOLERANCES:
UNLESS OTHERWISE SPECIFIED:
DECIMAL ±.XX = .03
DECIMAL ±.XXX = .005
FRACTIONAL ±1/64
ANGLES ±0°-30'
DR BY: JDK 10/4/95
CK BY: TRL 10/9/95
APP BY: GMP 10/12/95
CRETE MACHINE, INC.
3.5 VISE
SIZE C
FSCM NO NA
DWG NO V3.5-1
SCALE FULL
SHEET 2 OF 3

3.5 VISE


MATERIAL LIST– 3.5 VISE
ITEM PART NO PART NAME QTY REQ'D MATERIAL
3 V3.5-3 BASE JAW PLATE 1 SAE 3140
4 V3.5-4 SLIDING JAW PLATE 1 SAE 3140
5 V3.5-5 VISE SCREW 1 SAE 3140
6 V3.5-6 HANDLE 1 CRS
7 V3.5-7 HANDLE CAP 1 CRS
8 V3.5-8 PRESSURE PLATE 1 SAE 3140
1/16 CHAMFER (TYP)
1/4-28 UNF-2B x 0.40 DEEP
Ø0.625
1/4-28 UNF-2A
45° CHAMFER
5/8-8 ACME
Ø 5/16
2 HOLES
45° x 45° NOTCH
0.10 DEEP
1/4-28 UNF-2B
2 PLACES
R0.100
TOLERANCES:
UNLESS OTHERWISE SPECIFIED:
DECIMAL ±.XX = .03
DECIMAL ±.XXX = .005
FRACTIONAL ±1/64
ANGLES ±0°30'
GENERAL NOTES:
UNLESS OTHERWISE SPECIFIED:
1. BREAK ALL SHARP CORNERS.
2. DEBURR HOLES AND SHARP EDGES.
3. MACHINE SURFACES TO 250 MICROINCH.
DR BY: JDK 10/9/95
CK BY: TRL 10/11/95
APP BY: GMP 10/13/95
CRETE MACHINE, INC.
3.5 VISE
DWG NO V3.5-2
SCALE FULL
SHEET 3 OF 3

3.5 VISE

⊥ .002 X

Appendix

ABBREVIATIONS...

A

Absolute	ABS
Accelerate	ACCEL
Access panel	AP
Accessory	ACCESS.
Account	ACCT
Accumulator	ACC
Actual	ACT.
Adapter	ADPT
Addendum	ADD.
Adjust	ADJ
Advance	ADV
Aeronautic	AERO
Aeronautical Material Specifications	AMS
Aeronautical Standards Group	ASG
After	AFT.
Aggregate	AGGR
Air condition	AIR COND
Aircraft	ACFT
Air Force-Navy	AN
Air Force-Navy Aeronautical	ANA
Allowance	ALLOW.
Alloy	ALY
Alternate	ALT
Alternating Current	AC
Altitude	ALT
Aluminum	AL
Ambient	AMB
American Standard	AMER STD
American Standard Elevator Code	ASEC
American Wire Gage	AWG
Ammeter	AM.
Amount	AMT
Ampere	AMP
Amphibian—Amphibious	AMPH
Amplifier	AMPL
Amplitude Modulation	AM
Anneal	ANL
Antenna	ANT
Anti-Aircraft	AA
Anti-Friction Bearing	AFB
Apparatus	APPAR
Approved	APP
Approximate	APPROX
Arc weld	ARC/W
Area	A
Armament	ARMT
Armature	ARM.
Armor plate	ARM PL
Army-Navy-Air Force	ANAF
Arrangement	ARR
Asbestos	ASB
Asphalt	ASPH
Assemble	ASSEM
Assembly	ASSY
Assistant	ASST
Associate	ASSOC
Association	ASSN
Atomic	AT
Atomic Hydrogen Weld	AT/W
Audible	AUD
Audio Frequency	AF
Authorized	AUTH
Automatic	AUTO.
Automatic Frequency Control	AFC
Automatic Voltage Control	AVC
Auxiliary	AUX
Avenue	AVE
Average	AVG
Aviation	AVN
Avoirdupois	AVDP

B

Babbitt	BAB
Back-feed	BF
Back pressure	BP
Back to back	B to B
Backgear	BG
Balance	BAL
Ball bearing	BB
Barrel	BBL
Base line	BL
Base plate	BP
Battery	BAT. or BT
Baume'	BE.
Bearing	BRG
Beat frequency oscillator	BFO
Bell and flange	B&F
Bell and spigot	B&S
Bench mark	BM
Bending moment	M
Between	BET.
Between centers	BC
Bevel	BEV
Bill of material	B/M
Birmingham Wire Gage	BWG
Blank	BLK
Board	BD
Boiler	BLR
Bolster	BOLS
Bolt circle	BC
Both faces	BF
Both sides	BS
Both ways	BW
Bottom	BOT
Bottom chord	BC
Bottom face	BF
Bracket	BRKT
Brake	BK
Brake horsepower	BHP
Brass	BRS
Brazing	BRZG
Break	BRK
Brinell hardness	BH
British Standard	BR STD
British thermal units	BTU
Broach	BRO
Bronze	BRZ
Brown & Sharpe	B&S
Building	BLDG
Building line	BL
Bulkhead	BHD
Bureau of Standards	BU STD
Bushing	BUSH.
Button	BUT.
By-pass	BYP

C

Cabinet	CAB.
Cab over engine	COE
Cadmium plate	CD PL
Calculate	CALC
Caliber	CAL
Candlepower	CP
Capacitance	C
Capacity	CAP.
Cap screw	CAP SCR
Carbon	C
Carburetor	CARB
Carburize	CARB
Carriage	CRG
Carton	CTN
Case harden	CH
Cast (used with other materials)	C
Cast iron	CI
Cast iron pipe	CIP
Cast steel	CS
Casting	CSTG
Castle nut	CAS NUT
Catalog	CAT.
Cathode ray tube	CRT
Cavity	CAV
Ceiling	CLG
Cement	CEM
Center	CTR
Center line	CL
Center of gravity	CG
Center punch	CP
Center to center	C to C
Centigrade	C
Centrifugal	CENT.
Ceramic	CER
Chamfer	CHAM
Change	CHG
Change notice	CN
Change order	CO
Channel	CHAN
Check	CHK
Chemical	CHEM
Chord	CHD
Chrome molybdenum	CR MOLY
Chromium plate	Cr PL
Chrome vanadium	CR VAN.
Circle	CIR
Circuit	CKT
Circular pitch	CP
Circumference	CIRC
Clamp	CLP
Cleanout	CO
Clearance	CL
Clockwise	CW
Closet	CLO
Coated	CTD
Coaxial	COAX
Cold drawn	CD
Cold drawn steel	CDS
Cold finish	CF
Cold punched	CP
Cold rolled steel	CRS
Column	COL
Combination	COMB.
Command	COM
Commercial	COML
Commercial quality	CQ
Commutator	COMM
Companion	COMP
Compensator	COMP
Complete	COMPL
Compound	COMP
Compressor	COMPR
Concentric	CONC
Concrete	CONC
Condition	COND
Constant	CONST
Construction	CONSTR
Container	CNTR
Continue	CONT
Continuous wave	CW
Contract	CONTR
Contractor	CONTR
Contractor furnished equipment	CFE
Control	CONT
Conveyor	CNVR
Copper plate	COP PL
Correct	CORR
Corrosion resistant	CRE
Corrosion resistant steel	CRES
Corrugate	CORR
Cotter	COT.
Cotton webbing	COT. WEB.
Counterclockwise	CCW
Counter electromotive force	CEMF
Counterbore	CBORE
Counterdrill	CDRILL
Counterpunch	CPUNCH
Countersink	CSK
Countersink other side	CSKO
Coupling	CPLG
Cowling	COWL.
Crankcase	CRKC
Cross arm	XARM
Cross section	XSECT
Cubic	CU
Cubic feet per minute	CFM
Cubic feet per second	CFS
Cubic foot	CU FT
Cubic inch	CU IN.
Cubic inches per minute	CIPM
Cubic yard	CU YD
Current	CUR.
Cyanide	CYN
Cycle	CY
Cylinder	CYL

D

Decalcomania	DECAL
Decibel	DB
Decimal	DEC
Deck	DK
Dedendum	DED
Deep drawn	DD
Degree	(°) DEG
Density	D
Department	DEPT
Design	DSGN
Designed water line	DWL
Detail	DET
Detent	DET
Develop	DEV
Diagonal	DIAG
Diagram	DIAG
Diameter	DIA
Diametral pitch	DP
Diaphragm	DIAPH
Direct current	DC
Discharge	DISCH
Ditto	DO.
Division	DIV
Dovetail	DVTL
Dowel	DWL
Downspout	DS
Drafting	DFTG
Draftsman	DFTSMN
Drain	DR
Drawing	DWG
Drawing list	DL
Drill	DR
Drill rod	DR
Drive	DR
Drive fit	DF
Drop forge	DF
Duplex	DX
Duplicate	DUP

E

Each	EA
Eccentric	ECC
Effective	EFF
Effective horsepower	EHP
Efficiency	EFF
Elastic limit	EL
Elbow	ELL.
Electric	ELEC
Electromotive force	EMF
Elementary	ELEM
Elevate	ELEV
Elevation	EL
Elongation	ELONG
Enamel	E
Enclose	ENCL
End to end	E to E
Engine	ENG
Engineer	ENGR
Engineering	ENGRG
Engineering Change Order	ECO
Entrance	ENT
Envelope	ENV
Equal	EQ
Equipment	EQUIP.
Equipment & Spare Parts	E&SP
Equivalent	EQUIV
Estimate	EST
Excavate	EXC
Exchange	EXCH
Executive	EXEC
Exhaust	EXH
Existing	EXIST.
Expansion (joint)	EXP
Explosion Proof	EP
Extension	EXT
Exterior	EXT
Extra heavy	X HVY
Extra strong	X STR
Extrude	EXTR

F

Fabricate	FAB
Face to face	F to F
Fahrenheit	F
Far side	FS

...ABBREVIATIONS...

Farads	F
Federal	FED.
Federal Specification	FS
Federal Stock Number	FSN
Feeder	FDR
Feet	(′) FT
Feet board measure	FBM
Feet per minute	FPM
Feet per second	FPS
Female	FEM
Fiber	FBR
Figure	FIG.
Fillet	FIL
Fillister	FIL
Filter	FLT
Finish	FIN.
Finish all over	FAO
Fire door	F DR
Fire hose	FH
Fire hydrant	FHY
Fireproof	FPRF
Fitting	FTG
Fixture	FIX.
Flange	FLG
Flashing	FL
Flat	F
Flat head	FH
Flexible	FLEX.
Floor	FL
Floor drain	FD
Floor line	FL
Flow meter	FM
Fluid	FL
Fluorescent	FLUOR
Foot	(′) FT
Foot candle	FC
Forged steel	FST
Forging	FORG
Forward	FWD
Foundation	FDN
Foundry	FDRY
Fractional	FRAC
Fractional horsepower	FHP
Frame	FR
Framework	FRWK
Frequency	FREQ
Frequency modulation	FM
Front	FR
Furnish	FURN
Fuselage	FUS
G	
Gage	GA
Gallon	GAL
Gallons per minute	GPM
Galvanize	GALV
Galvanized iron	GI
Galvanized steel	GS
Galvanized steel wire rope	GSWR
Gasket	GSKT
General	GEN
Generator	GEN
Girder	G
Glass	GL
Government	GOVT
Grade	GR
Grade line	GL
Graphic	GRAPH.
Graphite	GPH
Grid	G
Grind	GRD
Grommet	GROM
Groove	GRV
Ground	GND or GRD
H	
Half-hard	½H
Half-round	½RD
Handle	HDL
Hanger	HGR
Hard	H
Hard-drawn	HD
Harden	HDN
Hardware	HDW
Head	HD
Headless	HDLS
Heat	HT
Heat exchanger	HE
Heat treat	HT TR
Heavy	HVY
Height	HGT
Henries	H
Hexagon	HEX.
High frequency	HF
High-pressure	HP
High-speed	HS
High-speed steel	HSS
High-tensile cast iron	HTCI
High-tensile steel	HTS
Highway	HWY
Horizontal	HORIZ
Horsepower	HP
Hot rolled	HR
Hot rolled steel	HRS
Hot water tank	HWT
Hour	HR
Hundredweight	CWT
Hydraulic	HYD
Hydrostatic	HYDRO
I	
Ignition	IGN
Impregnate	IMPG
Inboard	INBD
Incandescent	INCAND
Inch	(″) IN.
Inches per minute	IPM
Incorporated	INC
Indicate	IND
Inductance	L
Industrial	IND
Inside diameter	ID
Inspect	INSP
Install	INSTL
Insulate	INS
Intensifier	INT
Interchangeable	INTCHG
Intercommunication	INTERCOM
Interior	INT
Intermediate frequency	IF
Internal	INT
International Annealed Copper Standard	IACS
International Pipe Standard	IPS
Interphone control station	ICS
Intersect	INT
Iron	I
Iron-pipe size	IPS
Irregular	IRREG
Issue	ISS
J	
Job order	JO
Joint	JT
Journal	JNL
Junction	JCT
Junior	JR
K	
Key	K
Keyseat	KST
Keyway	KWY
Kiln-dried	KD
Kilocycle	KC
Kilohm	K
Kilowatt hour	KWH
Kilovolt	KV
Kip (1000 lb)	K
Knocked down	KD
Knockout	KO
L	
Laboratory	LAB
Lacquer	LAQ
Laminate	LAM
Lateral	LAT.
Lavatory	LAV
Lead covered	LC
Leading edge	LE
Left	L
Left hand	LH
Length	LG
Length over all	LOA
Letter	LTR
Light	LT
Limit	LIM
Line	L
Linear	LIN
Liquid	LIQ
Lithograph	LITHO
Locate	LOC
Long	LG
Loudspeaker	LS
Low frequency	LF
Low pressure	LP
Low-speed	LS
Lubricate	LUB
Lubricator	LUB
Lumber	LBR
M	
Machine	MACH.
Machine steel	MS
Magnaflux	M
Maintenance	MAINT
Male & female	M&F
Malleable	MALL.
Malleable iron	MI
Manual	MAN.
Manufacture	MFR
Manufactured	MFD
Manufacturing	MFG
Marine	MAR.
Mark	MK
Material	MATL
Material list	ML
Maximum	MAX
Mechanical	MECH
Median	MED
Megacycle	MC
Megohm	MEG
Memorandum	MEMO
Metal	MET.
Meter (instrument or measure of length)	M
Metered flow	MF
Mezzanine	MEZZ
Micro (10^{-6})	μ or U
Micrometer	MIC
Mile	MI
Miles per gallon	MPG
Miles per hour	MPH
Military	MIL
Millihenries	MH
Millimeter	MM
Minimum	MIN
Minute	(′) MIN
Miscellaneous	MISC
Mixture	MIX.
Model	MOD
Mold line	ML
Molded	MLD
Molding	MLDG
Month	MO
Monument	MON
Morse taper	MOR T
Motor	MOT
Mounted	MTD
Mounting	MTG
Multiple	MULT
Music wire gage	MWG
N	
Nameplate	NP
National	NATL
National Aircraft Standards	NAS
National Electrical Code	NEC
Natural	NAT
Naval architect	NA
Near face	NF
Near side	NS
Negative	NEG
New British Standard (Imperial Wire Gage)	NBS
Nipple	NIP.
Nominal	NOM
Noon	M
Normal	NORM.
North	N
Not to scale	NTS
Number	NO.
O	
Obsolete	OBS
Octagon	OCT
Office	OFF.
Ohms	Ω
On center	OC
One pole	1 P
Opening	OPNG
Opposite	OPP
Optical	OPT
Ordinance	ORD
Original	ORIG
Oscillator	ORC
Ounce	OZ
Outboard	OUTBD
Outlet	OUT.
Outside diameter	OD
Overall	OA
Overflow	OVFL
Overhead	OVHD
Oxidized	OXD
P	
Pack	PK
Packing	PKG
Page	P
Pair	PR
Panel	PNL
Paragraph	PARA
Parallel	PAR.
Parkway	PKWY
Part	PT
Passage	PASS.
Patent	PAT.
Pattern	PATT
Peck	PK
Penny (nails, etc.)	d
Permanent	PERM
Perpendicular	PERP
Phenolic	PHEN
Phosphor bronze	PH BRZ
Pick up	PU
Piece	PC
Piece mark	PC MK
Pint	PT
Pipe tap	PT
Pitch	P
Pitch circle	PC
Pitch diameter	PD
Plaster	PLAS
Plastic	PLSTC
Plate	PL
Plumbing	PLMB
Pneumatic	PNEU
Point	PT
Pole	P
Polish	POL
Porcelain	PORC
Port	P
Portable	PORT.
Position	POS
Potential	POT.
Potentiometer	POT
Pound	LB
Pounds per square inch	PSI
Power	PWR
Power factor	PF
Precast	PRCST
Prefabricated	PREFAB
Preferred	PFD
Prepare	PREP
Press	PRS
Pressure	PRESS.
Pressure angle	PA.
Pressure controlled	PC
Pressure switch	PS
Primary	PRIM.
Process	PROC
Production	PROD.

...ABBREVIATIONS

Production order	PO
Profile	PF
Project	PROJ
Proposed	PROP.
Publication	PUB.
Pull box	PB
Pull switch	PS
Pulse modulation	PM
Pump, fixed displacement	PF
Pump, variable displacement	PV
Punch	PCH
Purchase	PUR
Push button	PB

Q

Quadrant	QUAD.
Quality	QUAL
Quantity	QTY
Quart	QT
Quarter-hard	¼ H
Quarter-round	¼ RD
Quartermaster Corps	QMC

R

Radial	RAD
Radio frequency	RF
Radius	R
Railroad	RR
Railway	RY
Ream	RM
Reassemble	REASM
Received	RECD
Receptacle	RECP
Record	REC
Rectangle	RECT
Rectifier	RECT
Reduce	RED.
Reducer	RED.
Reference	REF
Reference line	REF L
Register	REG
Regulator	REG
Reinforce	REINF
Relative humidity	RH
Relay	REL
Relief	REL
Remove	REM
Renewable	REN
Reproduce	REPRO
Require	REQ
Required	REQD
Requisition	REQ
Resistance	R
Retard	RET.
Return	RET.
Reverse	REV
Revise	REV
Revolution	REV
Revolutions per minute	RPM
Right	R
Right hand	RH
Rivet	RIV
Rockwell hardness	RH
Roller bearing	RB
Root diameter	RD
Root mean square	RMS
Round	RD

S

Schedule	SCH
Schematic	SCHEM
Screw	SCR
Sea level	SL
Seamless	SMLS
Secondary	SEC
Section	SECT.
Semi-finished	SF
Semi-fixed	SFXD
Semi-steel	SS
Separator	SEP
Serial	SER
Serrate	SERR
Servo	SERV
Set screw	SS
Sewer	SEW.
Shaft	SFT
Sheathing	SHTHG
Sheet	SH
Shop order	SO
Short wave	SW
Shoulder	SHLD
Shutoff valve	SOV
Side	S
Similar	SIM
Sink	SK
Sketch	SK
Sleeve	SLV
Sleeve bearing	SB
Slotted	SLOT.
Small	SM
Socket	SOC
Soft	S
Soil pipe	SP
Solenoid	SOL
Solenoid controlled, pilot operated	SOL PLT
Space	SP
Spare	SP
Special	SPL
Special treatment steel	STS
Specific gravity	SP GR
Specification	SPEC
Speed	SP
Spherical	SPHER
Split phase	SP PH
Spotfaced	SF
Spring	SPG
Square	SQ
Squirrel cage	SQ CG
Stainless	STN
Stainless steel	SST
Stairway	STWY
Standard	STD
Starboard	STBD
Station	STA
Steel	STL
Stock	STK
Storage	STOR
Straight	STR
Strainer	STR
Street	ST
Stress anneal	SA
Strip	STR
Structural	STR
Substitute	SUB.
Substructure	SUBSTR
Summary	SUM.
Supercharge	S CHG
Superintendent	SUPT
Supersede	SUPSD
Superstructure	SUPRSTR
Supervise	SUPV
Supplement	SUPP.
Supply	SUP.
Surface	SURF.
Survey	SURV
Switch	SW
Switch and relay types	SP SW
Single pole switch	
Single pole single throw switch	SPST SW
Single pole double throw switch	SPDT SW
Double pole switch	DP SW
Double pole single throw switch	DPST SW
Double pole double throw switch	DPDT SW
Triple pole switch	3P SW
Triple pole single throw switch	3PST SW
Triple pole double throw switch	3PDT SW
4 pole switch	4P SW
4 pole single throw switch, etc.	4PST SW
4 pole double throw switch	4PDT SW
Switchboard	SWBD
Switchgear	SWGR
Symbol	SYM
Symmetrical	SYM
Synchronous	SYN
Synthetic	SYN
System	SYS

T

Tabulate	TAB.
Tachometer	TACH
Tangent	TAN.
Taper	TPR
Technical	TECH
Technical manual	TM
Technical report	TR
Tee	T
Teeth	T
Teeth per inch	TPI
Temperature	TEMP
Template	TEMP
Tensile strength	TS
Tension	TENS.
Terminal	TERM.
That is	i.e.
Thermal	THRM
Thick	THK
Thousand	M
Thousand foot pounds	KIP-FT
Thousand pound	KIP
Thread	THD
Threads per inch	TPI
Through	THRU
Timber	TMBR
Time	T
Time delay	TD
Tobin-bronze	TOB BRZ
Toggle	TGL
Tolerance	TOL
Tongue & groove	T&G
Tool steel	TS
Tooth	T
Total	TOT.
Total indicator reading	TIR
Trailing edge	TE
Training	TNG
Transfer	TRANS
Transformer	TRANS
Transistor	Q
Transmission	XMSN
Transportation	TRANS
Truss	T
Tubing	TUB.
Typical	TYP

U

Ultimate	ULT
Ultra-high frequency	UHF
United States Gage	USG
United States Standard	USS
Universal	UNIV

V

Vacuum	VAC
Vacuum tube	VT
Vacuum tube voltmeter	VTVM
Valve	V
Vandyke	VD
Vapor proof	VAP PRF
Varnish	VARN
Velocity	V
Vent pipe	VP
Ventilate	VENT.
Vertical	VERT
Very-high frequency	VHF
Vibrate	VIB
Video frequency	VF
Vitreous	VIT
Volt	V
Voltmeter	VM
Volume	VOL

W

Wall	W
Washer	WASH.
Water heater	WH
Water line	WL
Watt	W
Week	WK
Weight	WT
West	W
Wheel base	WB
Width	W
Wire	W
With	W/
Without	W/O
Woodruff	WDF
Wrought	WRT
Wrought iron	WI

Y

Yard	YD
Year	YR

SCREW THREAD ABBREVIATIONS

A

American National Coarse Thread	NC
American National Fine Thread	NF
American National Extra Fine Thread	NEF
American National Special Pitch, etc., Thread	NS
American National Pitch Thread	8N, 12N, or 18N
American National Acme Thread	NA
American National Taper Pipe Thread	NPT
American National Straight Pipe Thread in Pipe Couplings	NPSC
American National Straight Pipe Threads for Dry Seal Pressure Tight Joint	NPSF
American National Straight Pipe Threads for Mechanical Joints	NPSM
American National Taper Pipe Threads for Dry Seal Pressure Tight Joints	NPTF
American National Straight Pipe Threads for Locknuts and Locknut Pipe Threads	NPSL
American National Straight Pipe Threads for Hose Couplings and Nipples	NPSH
American National Taper Pipe Threads for Railing Fixtures	NPTR
American Truncated Whitworth Coarse Thread	TWC
American Truncated Whitworth Fine Thread	TWF
American Truncated Whitworth Special Thread	TWS

U

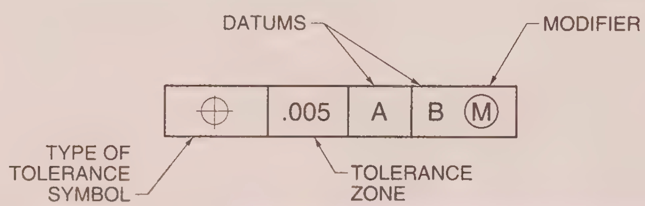
Unified National Coarse Thread	UNC
Unified National Fine Thread	UNF
Unified National Special Thread	UNS

INCH — MILLIMETER EQUIVALENTS*

Inches		MM	Inches		MM	Inches		MM
	.00004	.001		.11811	3		.550	13.970
	.00039	.01	1/8	.1250	3.175		.55118	14
	.00079	.02		.13780	3.5	9/16	.56250	14.2875
	.001	.025	9/64	.14063	3.5719		.57087	14.5
	.00118	.03		.150	3.810	37/64	.57813	14.6844
	.00157	.04	5/32	.15625	3.9688		.59055	15
	.00197	.05		.15748	4	19/32	.59375	15.0812
	.002	.051	11/64	.17188	4.3656		.600	15.24
	.00236	.06		.1750	4.445	39/64	.60938	15.4781
	.00276	.07		.17717	4.5		.61024	15.5
	.003	.0762	3/16	.18750	4.7625	5/8	.6250	15.875
	.00315	.08		.19685	5		.62992	16
	.00354	.09		.20	5.08	41/64	.64063	16.2719
	.00394	.1	13/64	.20313	5.1594		.64961	16.5
	.004	.1016		.21654	5.5		.650	16.51
	.005	.1270	7/32	.21875	5.5562	21/32	.65625	16.6688
	.006	.1524		.2250	5.715		.66929	17
	.007	.1778	15/64	.23438	5.9531	43/64	.67188	17.0656
	.00787	.2		.23622	6	11/16	.68750	17.4625
	.008	.2032	1/4	.250	6.35		.68898	17.5
	.009	.2286					.700	17.78
	.00984	.25		.25591	6.5	45/64	.70313	17.8594
	.01	.254	17/64	.26563	6.7469		.70866	18
	.01181	.3		.275	6.985	23/32	.71875	18.2562
1/64	.01563	.3969		.27559	7		.72835	18.5
	.01575	.4	9/32	.28125	7.1438	47/64	.73438	18.6531
	.01969	.5		.29528	7.5		.74803	19
	.02	.508	19/64	.29688	7.5406	3/4	.750	19.050
	.02362	.6		.30	7.62			
	.025	.635	5/16	.3125	7.9375	49/64	.76563	19.4469
	.02756	.7		.31496	8		.76772	19.5
	.0295	.75	21/64	.32813	8.3344	25/32	.78125	19.8438
	.03	.762		.33465	8.5		.78740	20
1/32	.03125	.7938	11/32	.34375	8.7375	51/64	.79688	20.2406
	.0315	.8		.350	8.89		.800	20.320
	.03543	.9		.35433	9		.80709	20.5
	.03937	1	23/64	.35938	9.1281	13/16	.81250	20.6375
	.04	1.016		.37402	9.5		.82677	21
3/64	.04687	1.191	3/8	.375	9.525	53/64	.82813	21.0344
	.04724	1.2	25/64	.39063	9.9219	27/32	.84375	21.4312
	.05	1.27		.39370	10		.84646	21.5
	.05512	1.4		.400	10.16		.850	21.590
	.05906	1.5	13/32	.40625	10.3188	55/64	.85938	21.8281
	.06	1.524		.41339	10.5		.86614	22
1/16	.06250	1.5875	27/64	.42188	10.7156	7/8	.875	22.225
	.06299	1.6		.43307	11		.88583	22.5
	.06693	1.7	7/16	.43750	11.1125	57/64	.89063	22.6219
	.07	1.778		.450	11.430		.900	22.860
	.07087	1.8		.45276	11.5		.90551	23
	.075	1.905	29/64	.45313	11.5094	29/32	.90625	23.0188
5/64	.07813	1.9844	15/32	.46875	11.9062	59/64	.92188	23.4156
	.07874	2		.47244	12		.92520	23.5
	.08	2.032	31/64	.48438	12.3031	15/16	.93750	23.8125
	.08661	2.2		.49213	12.5		.94488	24
	.09	2.286	1/2	.50	12.7		.950	24.130
	.09055	2.3				61/64	.95313	24.2094
3/32	.09375	2.3812		.51181	13		.96457	24.5
	0.9843	2.5	33/64	.51563	13.0969	31/32	.96875	24.6062
	.1	2.54	17/32	.53125	13.4938		.98425	25
	.10236	2.6		.53150	13.5	63/64	.98438	25.0031
7/64	.10937	2.7781	35/64	.54688	13.8906	1	1.0000	25.4

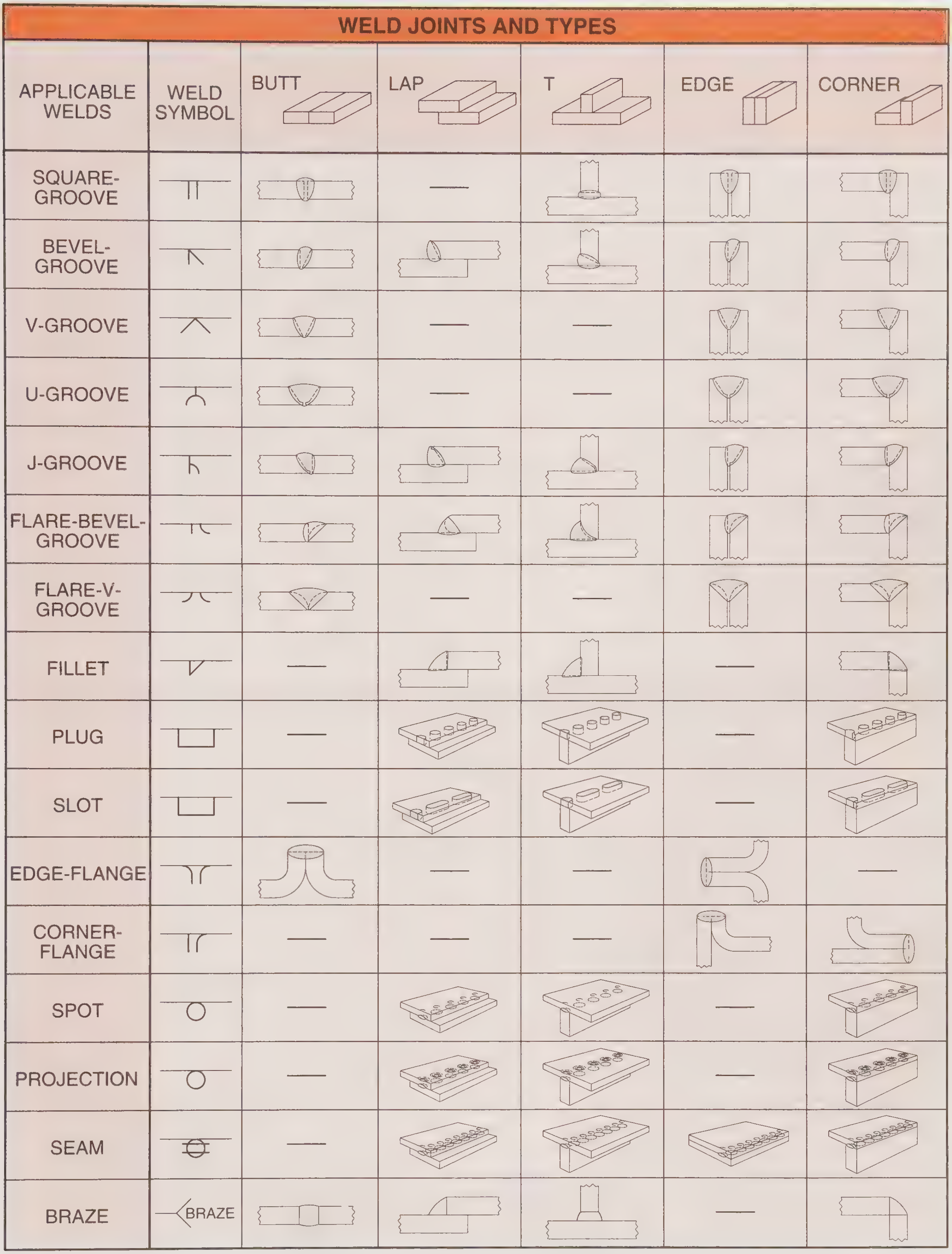
GEOMETRIC DIMENSIONING SYMBOLS

	TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL	ANSI
FOR INDIVIDUAL FEATURES	FORM	STRAIGHTNESS	⏤	6.4.1
		FLATNESS	⏥	6.4.2
		CIRCULARITY (ROUNDNESS)	○	6.4.3
		CYLINDRICITY	⌭	6.4.4
FOR INDIVIDUAL OR RELATED FEATURES	PROFILE	PROFILE OF A LINE	⌒	6.5.2 (b)
		PROFILE OF A SURFACE	⌓	6.5.2 (a)
FOR RELATED FEATURES	LOCATION	POSITION	⌖	5.2
		CONCENTRICITY	◎	5.11.3
	ORIENTATION	ANGULARITY	∠	6.6.2
		PERPENDICULARITY	⊥	6.6.4
		PARALLELISM	//	6.6.3
	RUNOUT	CIRCULAR RUNOUT	↗	6.7.2.1
		TOTAL RUNOUT	⌰	6.7.2.2

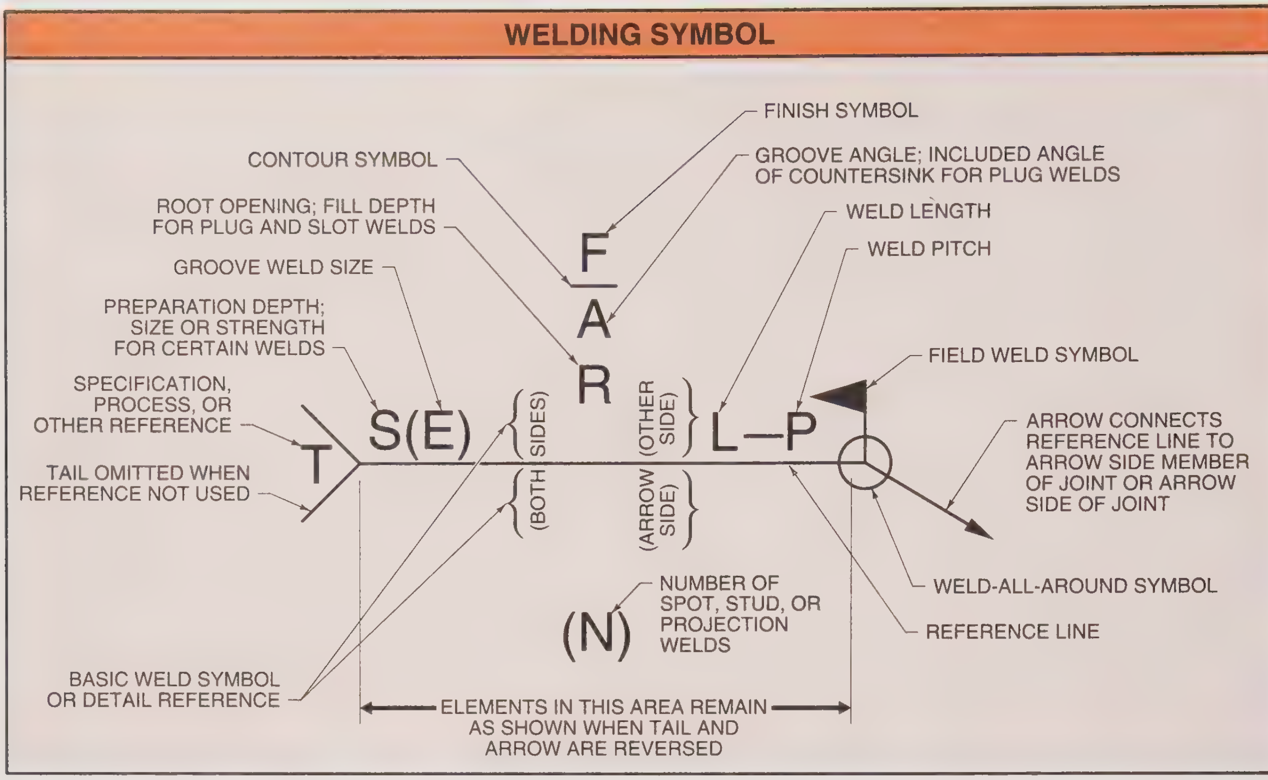


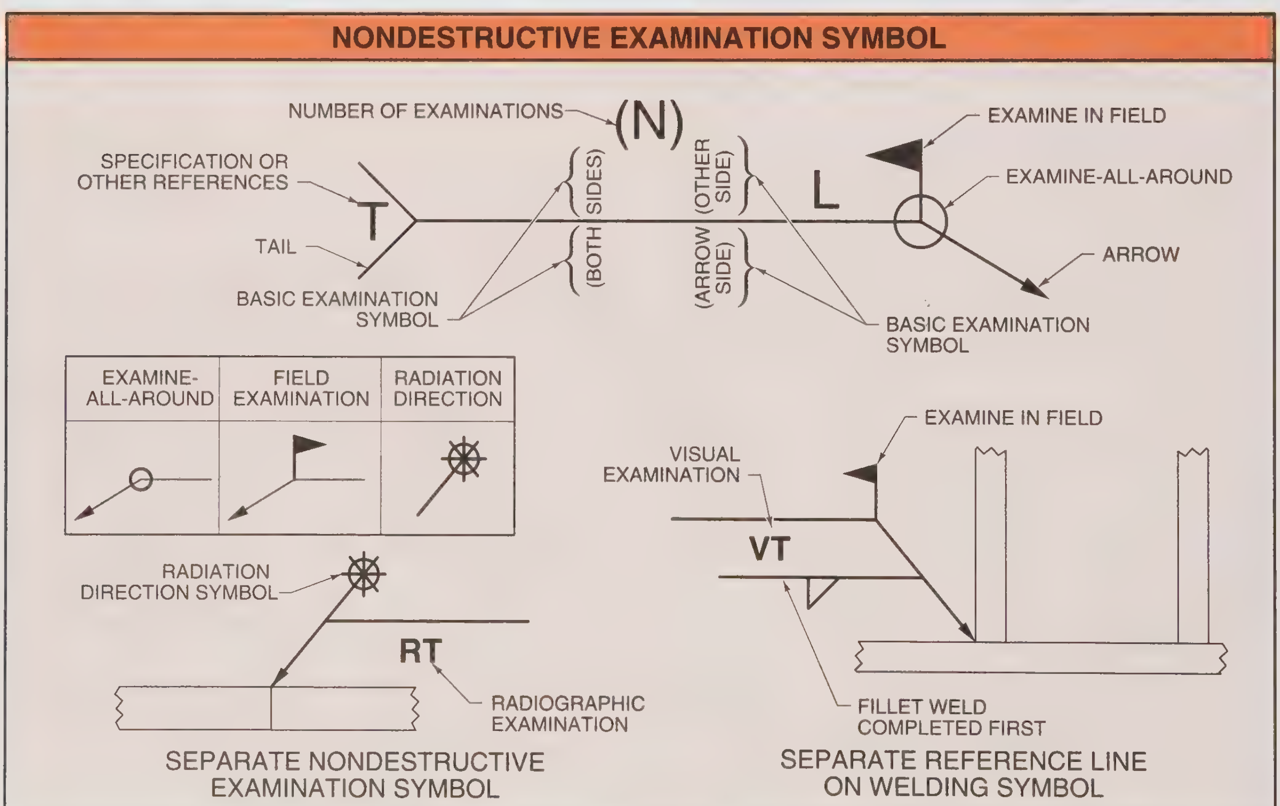
DATUMS

NUMBER	SYMBOLS	NUMBER	SYMBOLS
1	PRIMARY ⊥ .005 A	3	PRIMARY TERTIARY ⌖ Ø .014 Ⓜ F E D SECONDARY
2	PRIMARY ⌖ Ø .010 Ⓜ B C Ⓜ SECONDARY	MULTIPLE DATUM	MULTIPLE DATUM PRIMARY ↗ .002 A-B



WELD JOINTS AND TYPES						
APPLICABLE WELDS	WELD SYMBOL	BUTT	LAP	T	EDGE	CORNER
SQUARE-GROOVE			—			
BEVEL-GROOVE						
V-GROOVE			—	—		
U-GROOVE			—	—		
J-GROOVE						
FLARE-BEVEL-GROOVE						
FLARE-V-GROOVE			—	—		
FILLET		—			—	
PLUG		—			—	
SLOT		—			—	
EDGE-FLANGE			—	—		—
CORNER-FLANGE		—	—	—		
SPOT		—			—	
PROJECTION		—			—	
SEAM		—				
BRAZE	BRAZE		—		—	


WELDING SYMBOL
FINISH SYMBOL
CONTOUR SYMBOL
GROOVE ANGLE; INCLUDED ANGLE OF COUNTERSINK FOR PLUG WELDS
ROOT OPENING; FILL DEPTH FOR PLUG AND SLOT WELDS
WELD LENGTH
WELD PITCH
GROOVE WELD SIZE
F
A
R
PREPARATION DEPTH; SIZE OR STRENGTH FOR CERTAIN WELDS
FIELD WELD SYMBOL
SPECIFICATION, PROCESS, OR OTHER REFERENCE
S(E)
(BOTH SIDES)
(OTHER SIDE)
L—P
ARROW CONNECTS REFERENCE LINE TO ARROW SIDE MEMBER OF JOINT OR ARROW SIDE OF JOINT
T
TAIL OMITTED WHEN REFERENCE NOT USED
(ARROW SIDE)
NUMBER OF SPOT, STUD, OR PROJECTION WELDS
(N)
WELD-ALL-AROUND SYMBOL
REFERENCE LINE
BASIC WELD SYMBOL OR DETAIL REFERENCE
ELEMENTS IN THIS AREA REMAIN AS SHOWN WHEN TAIL AND ARROW ARE REVERSED


NONDESTRUCTIVE EXAMINATION SYMBOL
NUMBER OF EXAMINATIONS
(N)
EXAMINE IN FIELD
SPECIFICATION OR OTHER REFERENCES
(BOTH SIDES)
(OTHER SIDE)
L
EXAMINE-ALL-AROUND
T
TAIL
ARROW
(ARROW SIDE)
BASIC EXAMINATION SYMBOL
BASIC EXAMINATION SYMBOL
EXAMINE-ALL-AROUND
FIELD EXAMINATION
RADIATION DIRECTION
EXAMINE IN FIELD
VISUAL EXAMINATION
VT
RADIATION DIRECTION SYMBOL
RT
RADIOGRAPHIC EXAMINATION
FILLET WELD COMPLETED FIRST
SEPARATE NONDESTRUCTIVE EXAMINATION SYMBOL
SEPARATE REFERENCE LINE ON WELDING SYMBOL

METRIC TO ENGLISH EQUIVALENTS

	Unit	British Equivalent		
		cubic	*dry*	*liquid*
LENGTH	kilometer	.62 mi		
	hectometer	109.36 yd		
	dekameter	32.81′		
	meter	39.37″		
	decimeter	3.94″		
	centimeter	.39″		
	millimeter	.039″		
AREA	square kilometer	.3861 sq mi		
	hectacre	2.47 A		
	are	119.60 sq yd		
	square centimeter	.155 sq in.		
VOLUME	cubic centimeter	.061 cu in.		
	cubic decimeter	61.023 cu in.		
	cubic meter	1.307 cu yd		
CAPACITY	kiloliter	1.31 cu yd		
	hectoliter	3.53 cu ft	2.84 bu	
	dekaliter	.35 cu ft	1.14 pk	2.64 gal.
	liter	61.02 cu in.	.908 qt	1.057 qt
	cubic decimeter	61.02 cu in.	.908 qt	1.057 qt
	deciliter	6.1 cu in.	.18 pt	.21 pt
	centiliter	.61 cu in.		338 fl oz
	milliliter	.061 cu in.		.27 fl dr
MASS AND WEIGHT	metric ton	1.102 t		
	kilogram	2.2046 lb		
	hectogram	3.527 oz		
	dekagram	.353 oz		
	gram	.035 oz		
	decigram	1.543 gr		
	centigram	.154 gr		
	milligram	.015 gr		

ENGLISH TO METRIC EQUIVALENTS

		Unit	Metric Equivalent
LENGTH		mile	1.609 km
		rod	5.029 m
		yard	.9144 m
		foot	30.48 cm
		inch	2.54 cm
AREA		square mile	2.590 k^2
		acre	.405 hectacre, 4047 m^2
		square rod	25.293 m^2
		square yard	.836 m^2
		square foot	.093 m^2
		square inch	6.452 cm^2
VOLUME		cubic yard	.765 m^3
		cubic foot	.028 m^3
		cubic inch	16.387 cm^3
CAPACITY	*U.S. liquid measure*	gallon	3.785 l
		quart	.946 l
		pint	.473 l
		gill	118.294 ml
		fluidounce	29.573 ml
		fluidram	3.697 ml
		minim	.061610 ml
	U.S. dry measure	bushel	35.239 l
		peck	8.810 l
		quart	1.101 l
		pint	.551 l
	British imperial liquid and dry measure	bushel	.036 m^3
		peck	.0091 m^3
		gallon	4.546 l
		quart	1.136 l
		pint	568.26 cm^3
		gill	142.066 cm^3
		fluidounce	28.412 cm^3
		fluidram	3.5516 cm^3
		minim	.059194 cm^3
MASS AND WEIGHT	*avoirdupois*	short ton	.907 t
		long ton	1.016 t
		pound	.454 kg
		ounce	28.350 g
		dram	1.772 g
		grain	.0648 g
	troy	pound	.373 kg
		ounce	31.103 g
		pennyweight	1.555 g
		grain	.0648 g
	apothecaries'	pound	.373 kg
		ounce	31.103 g
		dram	3.888 g
		scruple	1.296 g
		grain	.0648 g

STANDARD SERIES THREADS — GRADED PITCHES

NOMINAL DIAMETER	UNC		UNF		UNEF	
	TPI	TAP DRILL	TPI	TAP DRILL	TPI	TAP DRILL
0 (.0600)			80	3/64		
1 (.0730)	64	No. 53	72	No. 53		
2 (.0860)	56	No. 50	64	No. 50		
3 (.0990)	48	No. 47	56	No. 45		
4 (.1120)	40	No. 43	48	No. 42		
5 (.1250)	40	No. 38	44	No. 37		
6 (.1380)	32	No. 36	40	No. 33		
8 (.1640)	32	No. 29	36	No. 29		
10 (.1900)	24	No. 25	32	No. 21		
12 (.2160)	24	No. 16	28	No. 14	32	No.13
1/4 (.2500)	20	No. 7	28	No. 3	32	7/32
5/16 (.3125)	18	F	24	I	32	9/32
3/8 (.3750)	16	5/16	24	Q	32	11/32
7/16 (.4375)	14	U	20	25/64	28	13/32
1/2 (.5000)	13	27/64	20	29/64	28	15/32
9/16 (.5625)	12	31/64	18	33/64	24	33/64
5/8 (.6250)	11	17/32	18	37/64	24	37/64
11/16 (.6875)					24	41/64
3/4 (.7500)	10	21/32	16	11/16	20	45/64
13/16 (.8125)					20	49/64
7/8 (.8750)	9	49/64	14	13/16	20	53/64
15/16 (.9375)					20	57/64

METRIC DRILL SIZES

DRILL DIAMETER						DRILL DIAMETER					
mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.
.40	.0157	1.95	.0768	4.70	.1850	8.00	.3150	13.20	.5197	25.50	1.0039
.42	.0165	2.00	.0787	4.80	.1890	8.10	.3189	13.50	.5315	26.00	1.0236
.45	.0177	2.05	.0807	4.90	.1929	8.20	.3228	13.80	.5433	26.50	1.0433
.48	.0189	2.10	.0827	5.00	.1969	8.30	.3268	14.00	.5512	27.00	1.0630
.50	.0197	2.15	.0846	5.10	.2008	8.40	.3307	14.25	.5610	27.50	1.0827
.55	.0217	2.20	.0866	5.20	.2047	8.50	.3346	14.50	.5709	28.00	1.1024
.60	.0236	2.25	.0886	5.30	.2087	8.60	.3386	14.75	.5807	28.50	1.1220
.65	.0256	2.30	.0906	5.40	.2126	8.70	.3425	15.00	.5906	29.00	1.1417
.70	.0276	2.35	.0925	5.50	.2165	8.80	.3465	15.25	.6004	29.50	1.1614
.75	.0295	2.40	.0945	5.60	.2205	8.90	.3504	15.50	.6102	30.00	1.1811
.80	.0315	2.45	.0965	5.70	.2244	9.00	.3543	15.75	.6201	30.50	1.2008
.85	.0335	2.50	.0984	5.80	.2283	9.10	.3583	16.00	.6299	31.00	1.2205
.90	.0354	2.60	.1024	5.90	.2323	9.20	.3622	16.25	.6398	31.50	1.2402
.95	.0374	2.70	.1063	6.00	.2362	9.30	.3661	16.50	.6496	32.00	1.2598
1.00	.0394	2.80	.1102	6.10	.2402	9.40	.3701	16.75	.6594	32.50	1.2795
1.05	.0413	2.90	.1142	6.20	.2441	9.50	.3740	17.00	.6693	33.00	1.2992
1.10	.0433	3.00	.1181	6.30	.2480	9.60	.3780	17.25	.6791	33.50	1.3189
1.15	.0453	3.10	.1220	6.40	.2520	9.70	.3819	17.50	.6890	34.00	1.3386
1.20	.0472	3.20	.1260	6.50	.2559	9.80	.3858	18.00	.7087	34.50	1.3583
1.25	.0492	3.30	.1299	6.60	.2598	9.90	.3898	18.50	.7283	35.00	1.3780
1.30	.0512	3.40	.1339	6.70	.2638	10.00	.3937	19.00	.7480	35.50	1.3976
1.35	.0531	3.50	.1378	6.80	.2677	10.20	.4016	19.50	.7677	36.00	1.4173
1.40	.0551	3.60	.1417	6.90	.2717	10.50	.4134	20.00	.7874	36.50	1.4370
1.45	.0571	3.70	.1457	7.00	.2756	10.80	.4252	20.50	.8071	37.00	1.4567
1.50	.0591	3.80	.1496	7.10	.2795	11.00	.4331	21.00	.8268	37.50	1.4764
1.55	.0610	3.90	.1535	7.20	.2835	11.20	.4409	21.50	.8465	38.00	1.4961
1.60	.0630	4.00	.1575	7.30	.2874	11.50	.4528	22.00	.8661	40.00	1.5748
1.65	.0650	4.10	.1614	7.40	.2913	11.80	.4646	22.50	.8858	42.00	1.6535
1.70	.0669	4.20	.1654	7.50	.2953	12.00	.4724	23.00	.9055	44.00	1.7323
1.75	.0689	4.30	.1693	7.60	.2992	12.20	.4803	23.50	.9252	46.00	1.8110
1.80	.0709	4.40	.1732	7.70	.3031	12.50	.4921	24.00	.9449	48.00	1.8898
1.85	.0728	4.50	.1772	7.80	.3071	12.80	.5039	24.50	.9646	50.00	1.9685
1.90	.0748	4.60	.1811	7.90	.3110	13.00	.5118	25.00	.9843		

TWIST DRILL FRACTIONAL, NUMBER, AND LETTER SIZES

Drill No.	Frac	Deci	Drill No.	Frac	Deci	Drill No.	Frac	Deci	Drill No.	Frac	Deci
80	—	.0135	42	—	.0935	7	—	.201	X	—	.397
79	—	.0145	—	3/32	.0938	—	13/64	.203	Y	—	.404
—	1/64	.0156				6	—	.204			
78	—	.0160	41	—	.0960	5	—	.206	—	13/32	.406
77	—	.0180	40	—	.0980	4	—	.209	Z	—	.413
			39	—	.0995				—	27/64	.422
76	—	.0200	38	—	.1015	3	—	.213	—	7/16	.438
75	—	.0210	37	—	.1040	—	7/32	.219	—	29/64	.453
74	—	.0225				2	—	.221			
73	—	.0240	36	—	.1065	1	—	.228	—	15/32	.469
72	—	.0250	—	7/64	.1094	A	—	.234	—	31/64	.484
			35	—	.1100				—	1/2	.500
71	—	.0260	34	—	.1110	—	15/64	.234	—	33/64	.516
70	—	.0280	33	—	.1130	B	—	.238	—	17/32	.531
69	—	.0292				C	—	.242			
68	—	.0310	32	—	.116	D	—	.246	—	35/64	.547
—	1/32	.0313	31	—	.120	—	1/4	.250	—	9/16	.562
			—	1/8	.125				—	37/64	.578
67	—	.0320	30	—	.129	E	—	.250	—	19/32	594
66	—	.0330	29	—	.136	F	—	.257	—	39/64	.609
65	—	.0350				G	—	.261			
64	—	.0360	—	9/64	.140	—	17/64	.266	—	5/8	.625
63	—	.0370	28	—	.141	H	—	.266	—	41/64	.641
			27	—	.144				—	21/32	.656
62	—	.0380	26	—	.147	I	—	.272	—	43/64	.672
61	—	.0390	25	—	.150	J	—	.277	—	11/16	.688
60	—	.0400				—	9/32	.281			
59	—	.0410	24	—	.152	K	—	281	—	45/64	.703
58	—	.0420	23	—	.154	L	—	.290	—	23/32	.719
			—	5/32	.156				—	47/64	.734
57	—	.0430	22	—	.157	M	—	.295	—	3/4	.750
56	—	.0465	21	—	.159	—	19/64	.2297	—	49/64	.766
—	3/64	.0469				N	—	.302			
55	—	.0520	20	—	.161	—	5/16	.313	—	25/32	.781
54	—	.0550	19	—	.166	O	—	.316	—	51/64	.797
			18	—	.170				—	13/16	.813
53	—	.0595	—	11/64	.172	P	—	.323	—	53/64	.828
—	1/16	.0625	17	—	.173	—	21/64	.328	—	27/32	.844
52	—	.0635				Q	—	.332			
51	—	.0670				R	—	.339			
50	—	.0700	16	—	.177	—	11/32	.344	—	55/64	.859
			15	—	.180				—	7/8	.875
49	—	.0730	14	—	.182	S	—	.348	—	57/64	.891
48	—	.0760	13	—	.185	T	—	.358	—	29/32	.906
—	5/64	.0781	—	3/16	.188	—	23/64	.359	—	59/64	.922
47	—	.0785				U	—	.368			
46	—	.0810	12	—	.189	—	3/8	.375	—	15/16	.938
			11	—	.191				—	61/64	.953
45	—	.0820	10	—	.194	V	—	.377	—	31/32	.969
44	—	.0860	9	—	.196	W	—	.386	—	63/64	.984
43	—	.0890	8	—	.199	—	25/64	.391	—	1	1.000

METRIC SCREW THREADS

Coarse (general purpose)		Fine	
Nom Size & Thd Pitch	Tap Drill Dia (mm)	Nom Size & Thd Pitch	Tap Drill Dia (mm)
M1.6 × 0.35	1.25	—	—
M1.8 × 0.35	1.45	—	—
M2 × 0.4	1.6	—	—
M2.2 × 0.45	1.75	—	—
M2.5 × 0.45	2.05	—	—
M3 × 0.5	2.50	—	—
M3.5 × 0.6	2.90	—	—
M4 × 0.7	3.30	—	—
M4.5 × 0.75	3.75	—	—
M5 × ..8	4.20	—	—
M6.3 × 1	5.30	—	—
M7 × 1	6.00	—	—
M8 × 1.25	6.80	M8 × 1	7.00
M9 × 1.25	7.75		
M10 × 1.5	8.50	M10 × 1.25	8.75
M11 × 1.5	9.50		
M12 × 1.75	10.30	M12 × 1.25	10.50
M14 × 2	12.00	M14 × 1.5	12.50
M16 × 2	14.00	M16 × 1.5	14.50
M18 × 2.5	15.50	M18 × 1.5	16.50
M20 × 2.5	17.50	M20 × 1.5	18.50
M22 × 2.5	19.50	M22 × 1.5	20.50
M24 × 3	21.00	M24 × 2	22.00
M27 × 3	24.00	M27 × 2	25.00
M30 × 3.5	26.50	M30 × 2	28.00
M33 × 3.5	29.50	M30 × 2	31.00
M36 × 4	32.00	M36 × 3	33.00
M39 × 4	35.00	M39 × 3	36.00
M42 × 4.5	37.50	M42 × 3	39.00
M45 × 4.5	40.50	M45 × 3	42.00
M48 × 5	43.00	M48 × 3	45.00
M52 × 5	47.00	M52 × 3	49.00
M56 × 5.5	50.50	M56 × 4	52.00
M60 × 5.5	54.50	M60 × 4	56.00
M64 × 6	58.00	M64 × 4	60.00
M68 × 6	62.00	M68 × 4	64.00
M72 × 6	66.00	—	—
M80 × 6	74.00	—	—
M90 × 6	84.00	—	—
M100 × 6	94.00	—	—

DRILLED HOLE TOLERANCES

Drill Size	Tolerance*	
	Plus	Minus
.0135 (No. 80) — .185 (No. 13)	.003	.002
.1875 — .246 (D)	.004	.002
.250 (E) — .750	.005	.002
.756 — 1.000	.007	.003
1.0156 — 2.000	.010	.004
2.0312 — 3.500	.015	.005

* generally accepted tolerances for good practice

AISI-SAE DESIGNATION SYSTEM

Type of Steel	Numbers and Digits	Nominal Alloy Content
Carbon	10xx	Plain carbon (1% Mn max)
	11xx	Resulfurized
	12xx	Resulfurized and rephosphorized
	15xx	Plain carbon (1.00% Mn — 1.65% Mn max)
Manganese	13xx	1.75% Mn
Nickel	23xx	3.5% Ni
	25xx	5% Ni
Nickel-chromium	31xx	1.25% Ni; .65% Cr and .80% Cr
	32xx	1.75% Ni; 1.07% Cr
	33xx	3.50% Ni; 1.50% Cr and 1.57% Cr
	34xx	3.00% Ni; .77% Cr
Molybdenum	40xx	.20% Mo and .25% Mo
	44xx	.40% Mo and .52% Mo
Chromium-molybdenum	41xx	.50% Cr, .80% Cr, and .95% Cr; .12% Mo, .20% Mo, .25% Mo, and .30% Mo
Nickel-chromium-molybdenum	43xx	1.82% Ni; .50% Cr and .80% Cr; .25% Mo
	43BVxx	1.82% Ni; .50% Cr; .12% Mo and .25% Mo; .03% V min
	47xx	1.05%Ni; .45%Cr; .20% Mo and .35% Mo
	81xx	.30% Ni; .40% Cr; .12% Mo
	86xx	.55% Ni; .50% Cr; .20% Mo
Nickel-chromium-molybdenum cont.	87xx	.55% Ni; .50% Cr; .25% Mo
	88xx	.55% Ni; .50% Cr; .35% Mo
	93xx	3.25% Ni; 1.20% Cr; .12% Mo
	94xx	.45% Ni; .40% Cr; .12% Mo
	97xx	.55% Ni; .20% Cr; .20% Mo
	98xx	1.00% Ni; .80% Cr; .25% Mo
Nickel-molybdenum	46xx	.85% Ni and 1.82% Ni; .20% Mo and .25% Mo
	48xx	3.50% Ni; .25% Mo
Chromium	50xx	.27% Cr, .40% Cr, .50% Cr, and .65% Cr
	51xx	.80% Cr, .87% Cr, .92% Cr, .95% Cr, 1.00% Cr, and 1.05% Cr
Chromium	50xxx	.50% Cr (C 1.00% min)
	51xxx	1.02% Cr (C 1.00% min)
	52xxx	1.45% Cr (C 1.00% min)
Chromium-vanadium	61xx	.60% Cr, .80% Cr, and .95% Cr; .10% V and .15% V min
Tungsten-chromium	72xx	1.75% W; .75% Cr
Silicon-manganese	92xx	1.40% Si and 2.00% Si; .65% Mn, .82% Mn, and .85% Mn; 0% Cr and .65% Cr
High-strength low-alloy	9xx	Various SAE grades
Boron	xxBxx	B denotes Boron steel
Leaded	xxLxx	L denotes Leaded steel

UNIFIED NUMBERING SYSTEM (UNS) FOR METALS AND ALLOYS

UNS Series	Metal
Nonferrous Metals and Alloys	
A00001 to A99999	Aluminum and aluminum alloys
C00001 to C99999	Copper and copper alloys
E00001 to E99999	Rare earth and rare earth-like metals and alloys
L00001 to L99999	Low melting metals and alloys
M00001 to M99999	Miscellaneous nonferrous metals and alloys
P00001 to P99999	Precious metals and alloys
R00001 to R99999	Reactive and refractory metals and alloys
Z00001 to Z99999	Zinc and zinc alloys
Ferrous Metals and Alloys	
D00001 to D99999	Specified mechanical property steels
F00001 to F99999	Cast irons
G00001 to G99999	AISI and SAE carbon and alloy steels (except tool steels)
H00001 to H99999	AISI H-steels
J00001 to J99999	Cast steels (except tool steels)
K00001 to K99999	Miscellaneous steels and ferrous alloys
S00001 to S99999	Heat and corrosion resistant (stainless) steels
T00001 to T99999	Tool steels

AISI-SAE, UNS NUMBERS — PLAIN CARBON, ALLOY, AND TOOL STEELS

AISI-SAE	UNS	AISI-SAE	UNS	AISI-SAE	UNS	AISI-SAE	UNS
Plain Carbon Steels							
1005	G10050	1030	G10300	1070	G10700	1566	G15660
1006	G10060	1035	G10350	1078	G10780	1110	G11100
1008	G10080	1037	G10370	1080	G10800	1117	G11170
1010	G10100	1038	G10380	1084	G10840	1118	G11180
1012	G10120	1039	G10390	1086	G10860	1137	G11370
1015	G10150	1040	G10400	1090	G10900	1139	G11390
1016	G10160	1042	G10420	1092	G10950	1140	G11400
1017	G10170	1043	G10430	1513	G15130	1141	G11410
1018	G10180	1044	G10440	1522	G15220	1144	G11440
1019	G10190	1045	G10450	1524	G15240	1146	G11460
1020	G10200	1046	G10460	1526	G15260	1151	G11510
1021	G10210	1049	G10490	1527	G15270	1211	G12110
1022	G10220	1050	G10500	1541	G15410	1212	G12120
1023	G10230	1053	G10530	1548	G15480	1213	G12130
1025	G10250	1055	G10550	1551	G15510	1215	G12150
1026	G10260	1059	G10590	1552	G15520	12L14	G12144
1029	G10290	1060	G10600	1561	G15610		
Alloy Steels							
1330	G13300	4150	G41500	5140	G51400	8642	G86420
1335	G13350	4161	G41610	5150	G51500	8645	G86450
1340	G13400	4320	G43200	5155	G51550	8655	G86550
1345	G13450	4340	G43400	5160	G51600	8720	G87200
4023	G40230	E4340	G43406	E51100	G51986	8740	G87400
4024	G40240	4615	G46150	E52100	G52986	8822	G88220
4027	G40270	4620	G46200	6118	G61180	9260	G92600
4028	G40280	4626	G46260	6150	G61500	50B44	G50441
4037	G40370	4720	G47200	8615	G86150	50B46	G50461
4047	G40470	4815	G48150	8617	G86170	50B50	G50501
4118	G41180	4817	G48170	8620	G86200	50B60	G50601
4130	G41300	4820	G48200	8622	G86220	51B60	G51601
4137	G41370	5117	G51170	8625	G86250	81B45	G81451
4140	G41400	5120	G51200	8627	G86270	94B17	G94171
4142	G41420	5130	G51300	8630	G86300	94B30	G94301
4145	G41450	5132	G51320	8637	G86370		
4147	G41470	5135	G51350	8640	G86400		
Tool Steels (AISI and UNS Only)							
M1	T11301	T6	T12006	A6	T30106	P4	T51604
M2	T11302	T8	T12008	A7	T30107	P5	T51605
M4	T11304	T15	T12015	A8	T30108	P6	T51606
M6	T11306	H10	T20810	A9	T30109	P20	T51620
M7	T11307	H11	T20811	A10	T30110	P21	T51621
M10	T11310	H12	T20812	D2	T30402	F1	T60601
M3-1	T11313	H13	T20813	D3	T30403	F2	T60602
M3-2	T11323	H14	T20814	D4	T30404	L2	T61202
M30	T11330	H19	T20819	D5	T30405	L3	T61203
M33	T11333	H21	T20821	D7	T30407	L6	T61206
M34	T11334	H22	T20822	O1	T31501	W1	T72301
M36	T11336	H23	T20823	O2	T31502	W2	T72302
M41	T11341	H24	T20824	O6	T31506	W5	T72305
M42	T11342	H25	T20825	O7	T31507	CA2	T90102
M43	T11343	H26	T20826	S1	T41901	CD2	T90402
M44	T11344	H41	T20841	S2	T41902	CD5	T90405
M46	T11346	H42	T20842	S4	T41904	CH12	T90812
M47	T11347	H43	T20843	S5	T41905	CH14	T90813
T1	T12001	A2	T30102	S6	T41906	CO1	T91501
T2	T12002	A3	T30103	S7	T41907	CS5	T91905
T4	T12004	A4	T30104	P2	T51602		
T5	T12005	A5	T30105	P3	T51603		

PIPE

NOMINAL ID (IN.)	OD (BW GAUGE)	INSIDE DIAMETER (BW GAUGE)			NOMINAL WALL THICKNESS		
		STD	XS	XXS	SCHEDULE 40	SCHEDULE 60	SCHEDULE 80
1/8	0.405	0.269	0.215		0.068	0.095	
1/4	0.540	0.364	0.302		0.088	0.119	
3/8	0.675	0.493	0.423		0.091	0.126	
1/2	0.840	0.622	0.546	0.252	0.109	0.147	0.294
3/4	1.050	0.824	0.742	0.434	0.113	0.154	0.308
1	1.315	1.049	0.957	0.599	0.133	0.179	0.358
1 1/4	1.660	1.380	1.278	0.896	0.140	0.191	0.382
1 1/2	1.900	1.610	1.500	1.100	0.145	0.200	0.400
2	2.375	2.067	1.939	1.503	0.154	0.218	0.436
2 1/2	2.875	2.469	2.323	1.771	0.203	0.276	0.552
3	3.500	3.068	2.900	2.300	0.216	0.300	0.600
3 1/2	4.000	3.548	3.364	2.728	0.226	0.318	
4	4.500	4.026	3.826	3.152	0.237	0.337	0.674
5	5.563	5.047	4.813	4.063	0.258	0.375	0.750
6	6.625	6.065	5.761	4.897	0.280	0.432	0.864
8	8.625	7.981	7.625	6.875	0.322	0.500	0.875
10	10.750	10.020	9.750	8.750	0.365	0.500	
12	12.750	12.000	11.750	10.750	0.406	0.500	

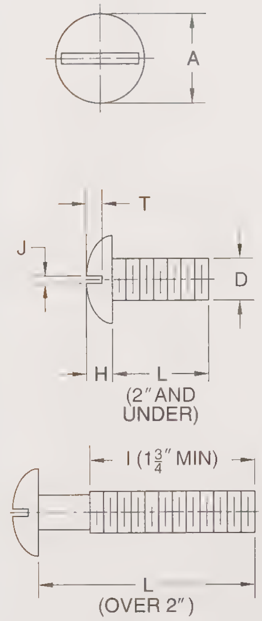
AMERICAN STANDARD BOLTS, NUTS, AND HEXAGON HEAD CAP SCREWS

Size*	Body Dia (Max)	Regular Bolts							Hex Cap Screws			Regular Nuts						
		Width†		Width‡		Height§			Width†‡		Height	Width†		Width‡		Thickness§		
		Sq	Hex	Sq	Hex	Sq	Hex	Semi-Fin Hex				Sq & Hex	Semi-Fin Hex	Sq	Hex; Semi-Fin Hex	Sq & Hex	Semi-Fin Hex	Semi-Fin Hex-Jam
1/4	.260	3/8	7/16	.530	.505	.188	.188	.163	7/16	.505	.163	7/16	7/16	.619	.505	.235	.219	.157
5/16	.324	1/2	1/2	.707	.577	.220	.235	.211	1/2	.577	.211	9/16	9/16	.795	.650	.283	.267	.189
3/8	.388	9/16	9/16	.795	.650	.268	.268	.243	9/16	.650	.243	5/8	5/8	.884	.722	.346	.330	.221
7/16	.452	5/8	5/8	.884	.722	.316	.316	.291	5/8	.722	.291	3/4	3/4	1.061	.866	.394	.378	.253
1/2	.515	3/4	3/4	1.061	.866	.348	.364	.323	3/4	.866	.323	13/16	13/16	1.149	.938	.458	.442	.317
9/16	—	—	—	—	—	—	—	—	13/16	.938	.371	7/8‖	7/8	—	1.010	.521‖	.505	.349
5/8	.642	15/16	15/16	1.326	1.083	.444	.444	.403	15/16	1.083	.403	1	1	1.414	1.155	.569	.553	.381
3/4	.768	1 1/8	1 1/8	1.591	1.299	.524	.524	.483	1 1/8	1.299	.483	1 1/8	1 1/8	1.591	1.299	.680	.665	.446
7/8	.895	1 5/16	1 5/16	1.856	1.516	.620	.604	.563	1 5/16	1.516	.563	1 5/16	1 5/16	1.856	1.516	.792	.776	.510
1	1.022	1 1/2	1 1/2	2.121	1.732	.684	.700	.627	1 1/2	1.732	.627	1 1/2	1 1/2	2.121	1.732	.903	.887	.575
1 1/8	1.149	1 11/16	1 11/16	2.386	1.949	.780	.780	.718	1 11/16	1.949	.718	1 11/16	1 11/16	2.386	1.949	1.030	.999	.639
1 1/4	1.277	1 7/8	1 7/8	2.652	2.165	.876	.876	.813	1 7/8	2.165	.813	1 7/8	1 7/8	2.652	2.165	1.126	1.094	.751
1 3/8	1.404	2 1/16	2 1/16	2.917	2.382	.940	.940	.878	2 1/16	2.382	.878	2 1/16	2 1/16	2.917	2.382	1.237	1.206	.815
1 1/2	1.531	2 1/4	2 1/4	3.182	2.598	1.036	1.036	.974	2 1/4	2.598	.974	2 1/4	2 1/4	3.182	2.598	1.348	1.317	.880
1 5/8	1.658	2 7/16	—	3.447	—	1.132	—	—	—	—	—	—	2 7/16	—	2.815#	—	1.429	.944
1 3/4	1.785	—	2 5/8	—	3.031	—	1.196	1.134	—	—	—	—	2 5/8	—	3.031#	—	1.540	1.009
1 7/8	—	—	—	—	—	—	—	—	—	—	—	—	2 13/16	—	3.248#	—	1.651	1.073
2	2.039	—	3	—	3.464	—	1.388	1.263	—	—	—	—	3	—	3.464#	—	1.763	1.138
2 1/4	2.305	—	3 3/8	—	3.897	—	1.548	1.423	—	—	—	—	3 3/8	—	3.897#	—	1.970	1.251
2 1/2	2.559	—	3 3/4	—	4.330	—	1.708	1.583	—	—	—	—	3 3/4	—	4.330#	—	2.193	1.505
2 3/4	2.827	—	4 1/8	—	4.763	—	1.869	1.744	—	—	—	—	4 1/8	—	4.763#	—	2.415	1.634
3	3.081	—	4 1/2	—	5.196	—	2.060	1.935	—	—	—	—	4 1/2	—	5.196#	—	2.638	1.763

* normal size or basic major diameter of thread
† across flats (maximum)
‡ across corners (maximum)
§ maximum
‖ hex only
\# semi-fin hex only

ROUND HEAD MACHINE SCREWS

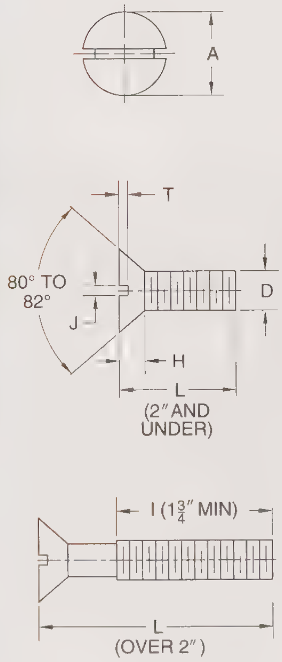
Nom Size	D	A		H		J		T	
	Screw Max Dia	Head Dia		Head Height		Slot Width		Slot Depth	
		Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.113	0.099	0.053	0.043	0.023	0.016	0.039	0.029
1	0.073	0.138	0.122	0.061	0.051	0.026	0.019	0.044	0.033
2	0.086	0.162	0.146	0.069	0.059	0.031	0.023	0.048	0.037
3	0.099	0.187	0.169	0.078	0.067	0.035	0.027	0.053	0.040
4	0.112	0.211	0.193	0.086	0.075	0.039	0.031	0.058	0.044
5	0.125	0.236	0.217	0.095	0.083	0.043	0.035	0.063	0.047
6	0.138	0.260	0.240	0.103	0.091	0.048	0.039	0.068	0.051
8	0.164	0.309	0.287	0.120	0.107	0.054	0.045	0.077	0.058
10	0.190	0.359	0.334	0.137	0.123	0.060	0.050	0.087	0.065
12	0.216	0.408	0.382	0.153	0.139	0.067	0.056	0.096	0.072
1/4	0.250	0.472	0.443	0.175	0.160	0.075	0.064	0.109	0.082
5/16	0.3125	0.590	0.557	0.216	0.198	0.084	0.072	0.132	0.099
3/8	0.375	0.708	0.670	0.256	0.237	0.094	0.081	0.155	0.117
7/16	0.4375	0.750	0.707	0.328	0.307	0.094	0.081	0.196	0.148
1/2	0.500	0.813	0.766	0.355	0.332	0.106	0.091	0.211	0.159
9/16	0.5625	0.938	0.887	0.410	0.385	0.118	0.102	0.242	0.183
5/8	0.625	1.000	0.944	0.438	0.411	0.133	0.116	0.258	0.195
3/4	0.750	1.250	1.185	0.547	0.516	0.149	0.131	0.320	0.242

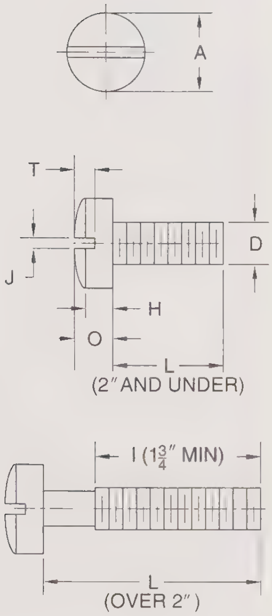


FLAT HEAD MACHINE SCREWS

Nom Size	D	A			H		J		T	
	Screw Max Dia	Head Dia			Head Height		Slot Width		Slot Depth	
		Max Sharp	Min Sharp	Abs Min*	Max	Min	Max	Min	Max	Min
0	0.060	0.119	0.105	0.101	0.035	0.026	0.023	0.016	0.015	0.010
1	0.073	0.146	0.130	0.126	0.043	0.033	0.026	0.019	0.019	0.012
2	0.086	0.172	0.156	0.150	0.051	0.040	0.031	0.023	0.023	0.015
3	0.099	0.199	0.181	0.175	0.059	0.048	0.035	0.027	0.027	0.017
4	0.112	0.225	0.207	0.200	0.067	0.055	0.039	0.031	0.030	0.020
5	0.125	0.252	0.232	0.225	0.075	0.062	0.043	0.035	0.034	0.022
6	0.138	0.279	0.257	0.249	0.083	0.069	0.048	0.039	0.038	0.024
8	0.164	0.332	0.308	0.300	0.100	0.084	0.054	0.045	0.045	0.029
10	0.190	0.385	0.359	0.348	0.116	0.098	0.060	0.050	0.053	0.034
12	0.216	0.438	0.410	0.397	0.132	0.112	0.067	0.056	0.060	0.039
1/4	0.250	0.507	0.477	0.462	0.153	0.131	0.075	0.064	0.070	0.046
5/16	0.3125	0.635	0.600	0.581	0.191	0.165	0.084	0.072	0.088	0.058
3/8	0.375	0.762	0.722	0.700	0.230	0.200	0.094	0.081	0.106	0.070
7/16	0.4375	0.812	0.771	0.743	0.223	0.190	0.094	0.081	0.103	0.066
1/2	0.500	0.875	0.831	0.802	0.223	0.186	0.106	0.091	0.103	0.065
9/16	0.5625	1.000	0.950	0.919	0.260	0.220	0.118	0.102	0.120	0.077
5/8	0.625	1.125	1.069	1.035	0.298	0.253	0.133	0.116	0.137	0.088
3/4	0.750	1.375	1.306	1.267	0.372	0.319	0.149	0.131	0.171	0.111

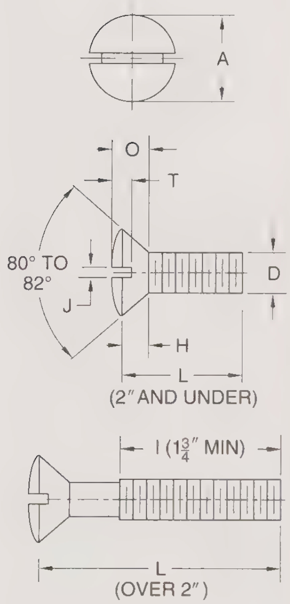
* with maximum sharpness





FILLISTER HEAD MACHINE SCREWS

Nom Size	D Screw Max Dia	A Head Dia		H Head Height		O Total Head Height		J Slot Width		T Slot Depth	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.096	0.083	0.045	0.037	0.059	0.043	0.023	0.016	0.025	0.015
1	0.073	0.118	0.104	0.053	0.045	0.071	0.055	0.026	0.019	0.031	0.020
2	0.086	0.140	0.124	0.062	0.053	0.083	0.066	0.031	0.023	0.037	0.025
3	0.099	0.161	0.145	0.070	0.061	0.095	0.077	0.035	0.027	0.043	0.030
4	0.112	0.183	0.166	0.079	0.069	0.107	0.088	0.039	0.031	0.048	0.035
5	0.125	0.205	0.187	0.088	0.078	0.120	0.100	0.043	0.035	0.054	0.040
6	0.138	0.226	0.208	0.096	0.086	0.132	0.111	0.048	0.039	0.060	0.045
8	0.164	0.270	0.250	0.113	0.102	0.156	0.133	0.054	0.045	0.071	0.054
10	0.190	0.313	0.292	0.130	0.118	0.180	0.156	0.060	0.050	0.083	0.064
12	0.216	0.357	0.334	0.148	0.134	0.205	0.178	0.067	0.056	0.094	0.074
1/4	0.250	0.414	0.389	0.170	0.155	0.237	0.207	0.075	0.064	0.109	0.087
5/16	0.3125	0.518	0.490	0.211	0.194	0.295	0.262	0.084	0.072	0.137	0.110
3/8	0.375	0.622	0.590	0.253	0.233	0.355	0.315	0.094	0.081	0.164	0.133
7/16	0.4375	0.625	0.589	0.265	0.242	0.368	0.321	0.094	0.081	0.170	0.135
1/2	0.500	0.750	0.710	0.297	0.273	0.412	0.362	0.106	0.091	0.190	0.151
9/16	0.5625	0.812	0.768	0.336	0.308	0.466	0.410	0.118	0.102	0.214	0.172
5/8	0.625	0.875	0.827	0.375	0.345	0.521	0.461	0.133	0.116	0.240	0.193
3/4	0.750	1.000	0.945	0.441	0.406	0.612	0.542	0.149	0.131	0.281	0.226



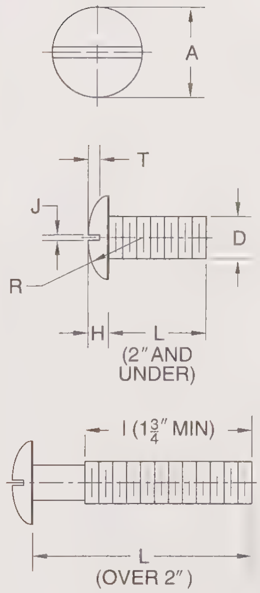
OVAL HEAD MACHINE SCREWS

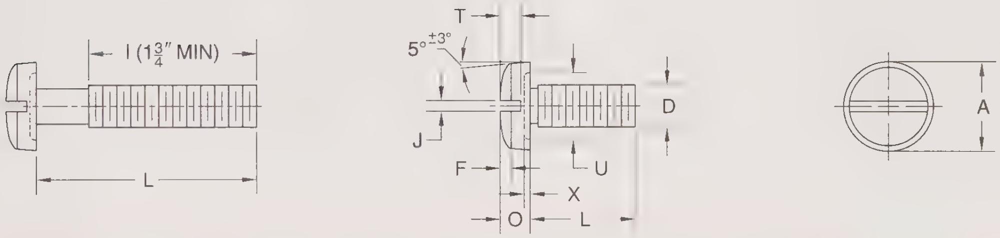
Nom Size	D Screw Max Dia	A Head Dia			H Head Height		O Total Head Height		J Slot Width		T Slot Depth	
		Max Sharp	Min Sharp	Abs Min*	Max	Min	Max	Min	Max	Min	Max	Min
0	0.060	0.119	0.105	0.101	0.035	0.026	0.056	0.041	0.023	0.016	0.030	0.025
1	0.073	0.146	0.130	0.126	0.043	0.033	0.068	0.052	0.026	0.019	0.038	0.031
2	0.086	0.172	0.156	0.150	0.051	0.040	0.080	0.063	0.031	0.023	0.045	0.037
3	0.099	0.199	0.181	0.175	0.059	0.048	0.092	0.073	0.035	0.027	0.052	0.043
4	0.112	0.225	0.207	0.200	0.067	0.055	0.104	0.084	0.039	0.031	0.059	0.049
5	0.125	0.252	0.232	0.225	0.075	0.062	0.116	0.095	0.043	0.035	0.067	0.055
6	0.138	0.279	0.257	0.249	0.083	0.069	0.128	0.105	0.048	0.039	0.074	0.060
8	0.164	0.332	0.308	0.300	0.100	0.084	0.152	0.126	0.054	0.045	0.088	0.072
10	0.190	0.385	0.359	0.348	0.116	0.098	0.176	0.148	0.060	0.050	0.103	0.084
12	0.216	0.438	0.410	0.397	0.132	0.112	0.200	0.169	0.067	0.056	0.117	0.096
1/4	0.250	0.507	0.477	0.462	0.153	0.131	0.232	0.197	0.075	0.064	0.136	0.112
5/16	0.3125	0.635	0.600	0.581	0.191	0.165	0.290	0.249	0.084	0.072	0.171	0.141
3/8	0.375	0.762	0.722	0.700	0.230	0.200	0.347	0.300	0.094	0.081	0.206	0.170
7/16	0.4375	0.812	0.771	0.743	0.223	0.190	0.345	0.295	0.094	0.081	0.210	0.174
1/2	0.500	0.875	0.831	0.802	0.223	0.186	0.354	0.299	0.106	0.091	0.216	0.176
9/16	0.5625	1.000	0.950	0.919	0.260	0.220	0.410	0.350	0.118	0.102	0.250	0.207
5/8	0.625	1.125	1.069	1.035	0.298	0.253	0.467	0.399	0.133	0.116	0.285	0.235
3/4	0.750	1.375	1.306	1.267	0.372	0.319	0.578	0.497	0.149	0.131	0.353	0.293

* with maximum sharpness

TRUSS HEAD MACHINE SCREWS

Nom Size	D	A		H		J		T		R
	Screw Max Dia	Head Dia		Head Height		Slot Width		Slot Depth		Rad
		Max	Min	Max	Min	Max	Min	Max	Min	Max
2	0.086	0.194	0.180	0.053	0.044	0.031	0.023	0.031	0.022	0.129
3	0.099	0.226	0.211	0.061	0.051	0.035	0.027	0.036	0.026	0.151
4	0.112	0.257	0.241	0.069	0.059	0.039	0.031	0.040	0.030	0.169
5	0.125	0.289	0.272	0.078	0.066	0.043	0.035	0.045	0.034	0.191
6	0.138	0.321	0.303	0.086	0.074	0.048	0.039	0.050	0.037	0.211
7	0.151	0.352	0.333	0.094	0.081	0.048	0.039	0.054	0.041	0.231
8	0.164	0.384	0.364	0.102	0.088	0.054	0.045	0.058	0.045	0.254
10	0.190	0.448	0.425	0.118	0.103	0.060	0.050	0.068	0.053	0.283
12	0.216	0.511	0.487	0.134	0.118	0.067	0.056	0.077	0.061	0.336
1/4	0.250	0.573	0.546	0.150	0.133	0.075	0.064	0.087	0.070	0.375
5/16	.03125	0.698	0.666	0.183	0.162	0.084	0.072	0.106	0.085	0.457
3/8	0.375	0.823	0.787	0.215	0.191	0.094	0.081	0.124	0.100	0.538
7/16	0.4375	0.948	0.907	0.248	0.221	0.094	0.081	0.142	0.116	0.619
1/2	0.500	1.073	1.028	0.280	0.250	0.106	0.091	0.161	0.131	0.701
9/16	0.5625	1.198	1.149	0.312	0.279	0.118	0.102	0.179	0.146	0.783
5/8	0.625	1.323	1.269	0.345	0.309	0.133	0.116	0.196	0.162	0.863
3/4	0.750	1.573	1.511	0.410	0.368	0.149	0.131	0.234	0.182	1.024

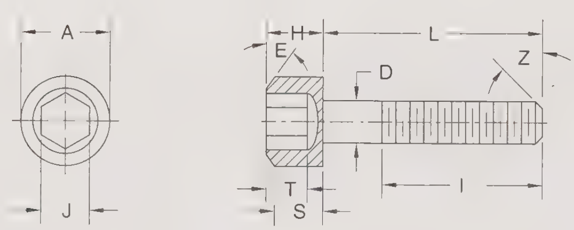




BINDING HEAD MACHINE SCREWS

Nom Size	D	A		O		J		T		F		U		X	
	Screw Max Dia	Head Dia		Total Head Height		Slot Width		Slot Depth		Oval Height		Undercut Dia		Undercut Depth	
		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
2	0.086	0.181	0.171	0.046	0.041	0.031	0.023	0.030	0.024	0.018	0.013	0.141	0.024	0.010	0.005
3	0.099	0.208	0.197	0.054	0.048	0.035	0.027	0.036	0.029	0.022	0.016	0.162	0.143	0.011	0.006
4	0.112	0.235	0.223	0.063	0.056	0.039	0.031	0.042	0.034	0.025	0.018	0.184	0.161	0.012	0.007
5	0.125	0.263	0.249	0.071	0.064	0.043	0.035	0.048	0.039	0.029	0.021	0.205	0.180	0.014	0.009
6	0.138	0.290	0.275	0.080	0.071	0.048	0.039	0.053	0.044	0.032	0.024	0.226	0.199	0.015	0.010
8	0.164	0.344	0.326	0.097	0.087	0.054	0.045	0.065	0.054	0.039	0.029	0.269	0.236	0.017	0.012
10	0.190	0.399	0.378	0.114	0.102	0.060	0.050	0.077	0.064	0.045	0.034	0.312	0.274	0.020	0.015
12	0.216	0.454	0.430	0.130	0.117	0.067	0.056	0.089	0.074	0.052	0.039	0.354	0.311	0.023	0.018
1/4	0.250	0.513	0.488	0.153	0.138	0.075	0.064	0.105	0.088	0.061	0.046	0.410	0.360	0.026	0.021
5/16	0.3125	0.641	0.609	0.193	0.174	0.084	0.072	0.134	0.112	0.077	0.059	0.513	0.450	0.032	0.027
3/8	0.375	0.769	0.731	0.234	0.211	0.094	0.081	0.163	0.136	0.094	0.071	0.615	0.540	0.039	0.034

HEXAGONAL SOCKET HEAD CAP SCREWS												
D			A		H		S			J		T
Body Dia			Head Dia		Head Height		Head Side-Height			Socket Width Across Flats		Key Depth
Nom	Max	Min	Max	Min	Max	Min	Nom	Max	Min	Max	Min	Min
0	0.060	0.0583	0.0960	0.0926	0.0600	0.0574	0.055	0.056	0.054	0.051	0.050	0.025
1	0.0730	0.0711	0.1180	0.1142	0.0730	0.0702	0.067	0.068	0.066	0.051	0.050	0.031
2	0.0860	0.0840	0.140	0.136	0.086	0.083	0.079	0.081	0.078	0.0635	1/16	0.038
3	0.0990	0.0968	0.161	0.157	0.099	0.096	0.091	0.093	0.089	0.0791	5/64	0.044
4	0.1120	0.1096	0.183	0.178	0.112	0.109	0.103	0.105	0.101	0.0791	5/64	0.051
5	0.1250	0.1226	0.205	0.200	0.125	0.122	0.115	0.117	0.113	0.0947	3/32	0.057
6	0.1380	0.1353	0.226	0.221	0.138	0.134	0.127	0.129	0.125	0.0947	3/32	0.064
8	0.1640	0.1613	0.270	0.265	0.164	0.160	0.150	0.152	0.148	0.1270	1/8	0.077
10	0.1900	0.1867	5/16	0.306	0.190	0.185	0.174	0.176	0.172	0.1582	5/32	0.090
12	0.2160	0.2127	11/32	0.337	0.216	0.211	0.198	0.200	0.196	0.1582	5/32	0.103
1/4	0.2500	0.2464	3/8	0.367	1/4	0.244	0.229	0.232	0.226	0.1895	3/16	0.120
5/16	0.3125	0.3084	7/16	0.429	5/16	0.306	0.286	0.289	0.283	0.2207	7/32	0.151
3/8	0.3750	0.3705	9/16	0.553	3/8	0.368	0.344	0.347	0.341	0.3155	5/16	0.182
7/16	0.4375	0.4326	5/8	0.615	7/16	0.430	0.401	0.405	0.397	0.3155	5/16	0.213
1/2	0.5000	0.4948	3/4	0.739	1/2	0.492	0.458	0.462	0.454	0.3780	3/8	0.245
9/16	0.5625	0.5569	13/16	0.801	9/16	0.554	0.516	0.520	0.512	0.3780	3/8	0.276
5/8	0.6250	0.6191	7/8	0.863	5/8	0.616	0.573	0.577	0.569	0.5030	1/2	0.307
3/4	0.7500	0.7436	1	0.987	3/4	0.741	0.688	0.693	0.684	0.5655	9/16	0.370
7/8	0.8750	0.8680	1 1/8	1.111	7/8	0.865	0.802	0.807	0.797	0.5655	9/16	0.432
1	1.0000	0.9924	1 5/16	1.297	1	0.989	0.917	0.922	0.912	0.6290	5/8	0.495
1 1/8	1.1250	1.1165	1 1/2	1.483	1 1/8	1.113	1.031	1.037	1.025	0.7540	3/4	0.557
1 1/4	1.2500	1.2415	1 3/4	1.733	1 1/4	1.238	1.146	1.152	1.140	0.7540	3/4	0.620
1 3/8	1.3750	1.3649	1 7/8	1.855	1 3/8	1.361	1.260	1.267	1.253	0.7540	3/4	0.682
1 1/2	1.5000	1.4899	2	1.979	1 1/2	1.485	1.375	1.382	1.368	1.0040	1	0.745

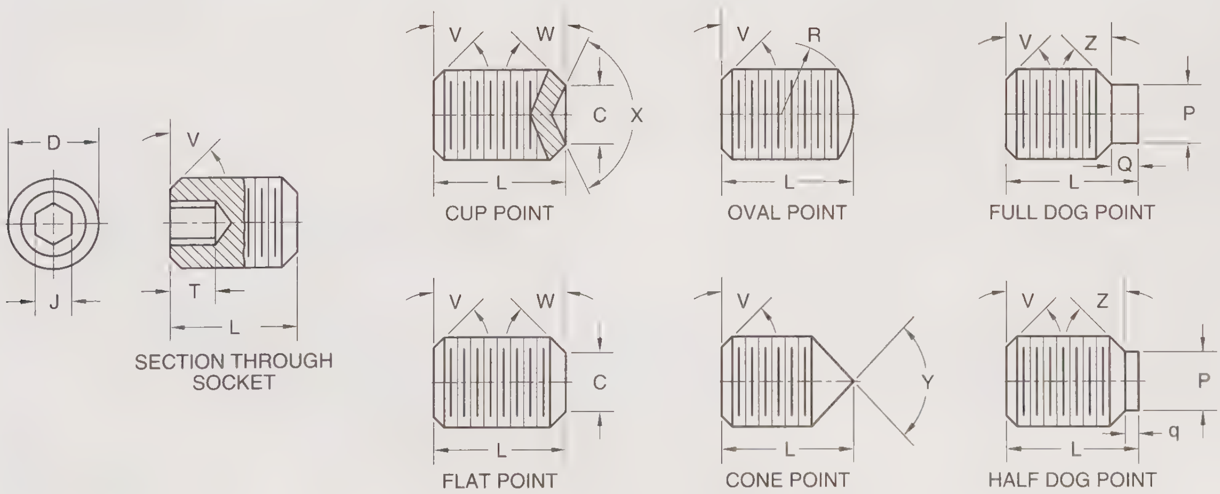


HEXAGONAL SOCKET SET SCREWS

D	C		R	Y		P		Q	q	J		T
Nom Dia	Cup and Flat Point Dia		Oval Point Radius	Cone Point Angle		Full and Half Dog Point				Socket Width Across Flats		Key Depth
				118° ± 2°*	90° ± 2°†	Dia		Full	Half			
	Max	Min				Max	Min			Max	Min	Min
0	0.033	0.027	3/64	1/16	5/64	0.040	0.037	0.030	0.015	0.0285	0.028	0.022
1	0.040	0.033	0.055	5/64	3/32	0.049	0.045	0.037	0.019	0.0355	0.035	0.028
2	0.047	0.039	1/16	3/32	7/64	0.057	0.053	0.043	0.022	0.0355	0.035	0.028
3	0.054	0.045	5/64	7/64	1/8	0.066	0.062	0.050	0.025	0.051	0.050	0.040
4	0.061	0.051	0.084	1/8	5/32	0.075	0.070	0.056	0.028	0.051	0.050	0.040
5	0.067	0.057	3/32	1/8	3/16	0.083	0.078	0.06	0.03	0.0635	1/16	0.050
6	0.074	0.064	7/64	1/8	3/16	0.092	0.087	0.07	0.035	0.0635	1/16	0.050
8	0.087	0.076	1/8	3/16	1/4	0.109	0.103	0.08	0.04	0.0791	5/64	0.062
10	0.102	0.088	9/64	3/16	1/4	0.127	0.120	0.09	0.045	0.0947	3/32	0.075
12	0.115	0.101	5/32	3/16	1/4	0.144	0.137	0.11	0.055	0.0947	3/32	0.075
1/4	0.132	0.118	3/16	1/4	5/16	5/32	0.149	1/8	1/16	0.1270	1/8	0.100
5/16	0.172	0.156	15/64	5/16	3/8	13/64	0.195	5/32	5/64	0.1582	5/32	0.125
3/8	0.212	0.194	9/32	3/8	7/16	1/4	0.241	3/16	3/32	0.1895	3/16	0.150
7/16	0.252	0.232	21/64	7/16	1/2	19/64	0.287	7/32	7/64	0.2207	7/32	0.175
1/2	0.291	0.270	3/8	1/2	9/16	11/32	0.334	1/4	1/8	0.2520	1/4	0.200
9/16	0.332	0.309	27/64	9/16	5/8	25/64	0.379	9/32	9/64	0.2520	1/4	0.200
5/8	0.371	0.347	15/32	5/8	3/4	15/32	0.456	5/16	5/32	0.3155	5/16	0.250
3/4	0.450	0.425	9/16	3/4	7/8	9/16	0.549	3/8	3/16	0.3780	3/8	0.300
7/8	0.530	0.502	21/32	7/8	1	21/32	0.642	7/16	7/32	0.5030	1/2	0.400
1	0.609	0.579	3/4	1	1 1/8	3/4	0.734	1/2	1/4	0.5655	9/16	0.450
1 1/8	0.689	0.655	27/32	1 1/8	1 1/4	27/32	0.826	9/16	9/32	0.5655	9/16	0.450
1 1/4	0.767	0.733	15/16	1 1/4	1 1/2	15/16	0.920	5/8	5/16	0.6290	5/8	0.500
1 3/8	0.848	0.808	1 1/32	1 3/8	1 5/8	1 1/32	1.011	11/16	11/32	0.6290	5/8	0.500
1 1/2	0.926	0.886	1 1/8	1 1/2	1 3/4	1 1/8	1.105	3/4	3/8	0.7540	3/4	0.600
1 3/4	1.086	1.039	1 5/16	1 3/4	2	1 5/16	1.289	7/8	7/16	1.0040	1	0.800
2	1.244	1.193	1 1/2	2	2 1/4	1 1/2	1.474	1	1/2	1.0040	1	0.800

* for these lengths and under

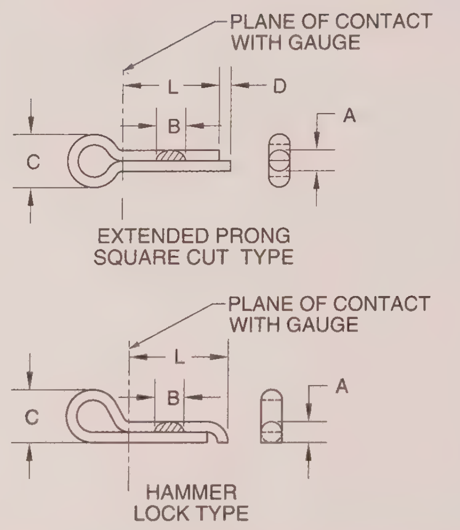
† for these lengths and over



COTTER PINS

Nom Size	Dia A & Width B Max	Wire Width B Min	Head Dia C Min	Prong Length D Min	Hole Size
1/32	.032	.022	0.06	.01	.047
3/64	.048	.035	0.09	.02	.062
1/16	.060	.044	0.12	.03	.078
5/64	.076	.057	0.16	.04	.094
3/32	.090	.069	0.19	.04	.109
7/64	.104	.080	0.22	.05	.125
1/8	.120	.093	0.25	.06	.141
9/64	.134	.104	0.28	.06	.156
5/32	.150	.116	0.31	.07	.172
3/16	.176	.137	0.38	.09	.203
7/32	.207	.161	0.44	.10	.234
1/4	.225	.176	0.50	.11	.266
5/16	.280	.220	0.62	.14	.312
3/8	.335	.263	0.75	.16	.375
7/16	.406	.320	0.88	.20	.438
1/2	.473	.373	1.00	.23	.500
5/8	.598	.472	1.25	.30	.625
3/4	.723	.572	1.50	.36	.750

COTTER PINS

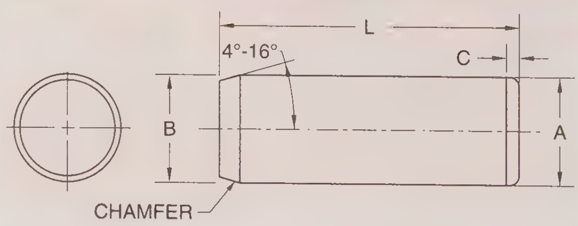


DOWEL PINS

Nom Size Pin Dia		Pin Dia A						Point Dia B		Crown Height or Radius C		Range of Preferred Lengths L	Double Shear Load*	Suggested Hole Dia	
		Standard Series Pins			Oversize Series Pins										
Frac	Deci	Basic	Max	Min	Basic	Max	Min	Max	Min	Max	Min			Max	Min
1/16	0.0625	0.0627	0.0628	0.0626	0.0635	0.0636	0.0634	0.058	0.048	0.020	0.008	3/16 - 3/4	800	0.0625	0.0620
5/64	0.0781	0.0783	0.0784	0.0782	0.0791	0.0792	0.0790	0.074	0.064	0.026	0.010	—	1240	0.0781	0.0776
3/32	0.0938	0.0940	0.0941	0.0939	0.0948	0.0949	0.0947	0.089	0.079	0.031	0.012	5/16 - 1	1800	0.0937	0.0932
1/8	0.1250	0.1252	01253	0.1251	0.1260	0.1261	0.1259	0.120	0.110	0.041	0.016	3/8 - 2	3200	0.1250	0.1245
5/32	0.1562	0.1564	0.1565	0.1563	0.1572	0.1573	0.1571	0.150	0.140	0.052	0.020	—	5000	0.1562	0.1557
3/16	0.1875	0.1877	0.1878	0.1876	0.1885	0.1886	0.1884	0.180	0.170	0.062	0.023	1/2 - 2	7200	0.1875	0.1870
1/4	0.2500	0.2502	0.2503	0.2501	0.2510	0.2511	0.2509	0.240	0.230	0.083	0.031	1/2 - 2 1/2	12,800	0.2500	0.2495
5/16	0.3125	0.3127	0.3128	0.3126	0.3135	0.3136	0.3134	0.302	0.290	0.104	0.039	1/2 - 2 1/2	20,000	0.3125	0.3120
3/8	0.3750	0.3752	0.3753	0.3751	0.3760	0.3761	0.3759	0.365	0.350	0.125	0.047	1/2 - 3	28,700	0.3750	0.3745
7/16	0.4375	0.4377	0.4378	0.4376	0.4385	0.4386	0.4384	0.424	0.409	0.146	0.055	7/8 - 3	39,100	0.4375	0.4370
1/2	0.5000	0.5002	0.5003	0.5001	0.5010	0.5011	0.5009	0.486	0.471	0.167	0.063	3/4, 1 - 4	51,000	0.5000	0.4995
5/8	0.6250	0.6252	0.6253	0.6251	0.6260	0.6261	0.6259	0.611	0.595	0.208	0.078	1 1/4 - 5	79,800	0.6250	0.6245
3/4	0.7500	0.7502	0.7503	0.7501	0.7510	0.7511	0.7509	0.735	0.715	0.250	0.094	1 1/2 - 6	114,000	0.7500	0.7495
7/8	0.8750	0.8752	0.8753	0.8751	0.8760	0.8761	0.8759	0.860	0.840	0.293	0.109	2, 2 1/2 - 6	156,000	0.8750	0.8745
1	1.0000	1.0002	1.0003	1.0001	1.0010	1.0011	1.0009	0.980	0.960	0.333	0.125	2, 2 1/2 - 5, 6	204,000	1.0000	0.9995

* minimum lb

DOWEL PINS

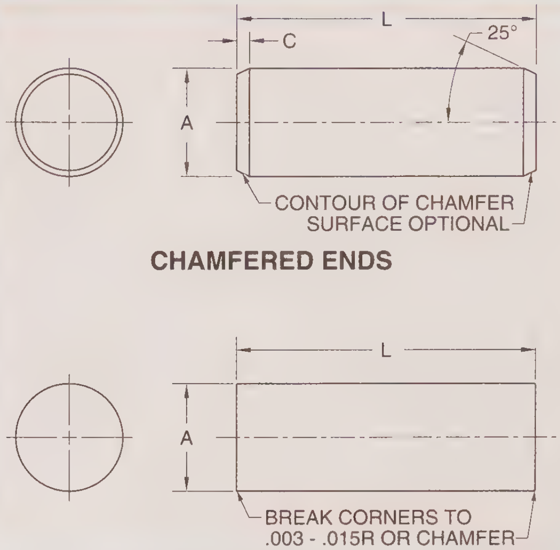


STRAIGHT PINS*

Nom Size or Basic Pin Dia		Pin Dia *A*		Chamfer Length *C*	
		Max	Min	Max	Min
1/16	0.062	0.0625	0.0605	0.025	0.005
3/32	0.094	0.0937	0.0917	0.025	0.005
7/64	0.109	0.1094	0.1074	0.025	0.005
1/8	0.125	0.1250	0.1230	0.025	0.005
5/32	0.156	0.1562	0.1542	0.025	0.005
3/16	0.188	0.1875	0.1855	0.025	0.005
7/32	0.219	0.2187	0.2167	0.025	0.005
1/4	0.250	0.2500	0.2480	0.025	0.005
5/16	0.312	0.3125	0.3105	0.040	0.020
3/8	0.375	0.3750	0.3730	0.040	0.020
7/16	0.438	0.4375	0.4355	0.040	0.020
1/2	0.500	0.5000	0.4980	0.040	0.020
5/8	0.625	0.6250	0.6230	0.055	0.035
3/4	0.750	0.7500	0.7480	0.055	0.035
7/8	0.875	0.8750	0.8730	0.055	0.035
1	1.000	1.0000	0.9980	0.055	0.035

* All dimensions are in inches.

STRAIGHT PINS



SQUARE ENDS

SPIRALLY COILED PINS

SPIRALLY COILED PINS

Nom Dia *D*	Decimal Dimension	Recommended Hole Tolerance	*H*		*B*	*D*		Min Double Shear	*E*†
		+	Min	Max		Min	Max	1070	
1/16	0.062	0.003	0.084	0.099	0.059	0.067	0.072	330	1/64
5/64	0.078	0.003	0.105	0.122	0.075	0.083	0.088	550	1/64
3/32	0.094	0.003	0.125	0.144	0.091	0.099	0.105	775	1/32
7/64	0.109	0.003	0.146	0.167	0.106	0.114	0.120	1050	1/32
1/8	0.125	0.004	0.166	0.189	0.121	0.131	0.138	1400	1/32
5/32	0.156	0.004	0.207	0.234	0.152	0.163	0.171	2200	3/64
3/16	0.187	0.005	0.248	0.279	0.182	0.196	0.205	3150	1/16

_L_ Lengths Available from Stock*

3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2

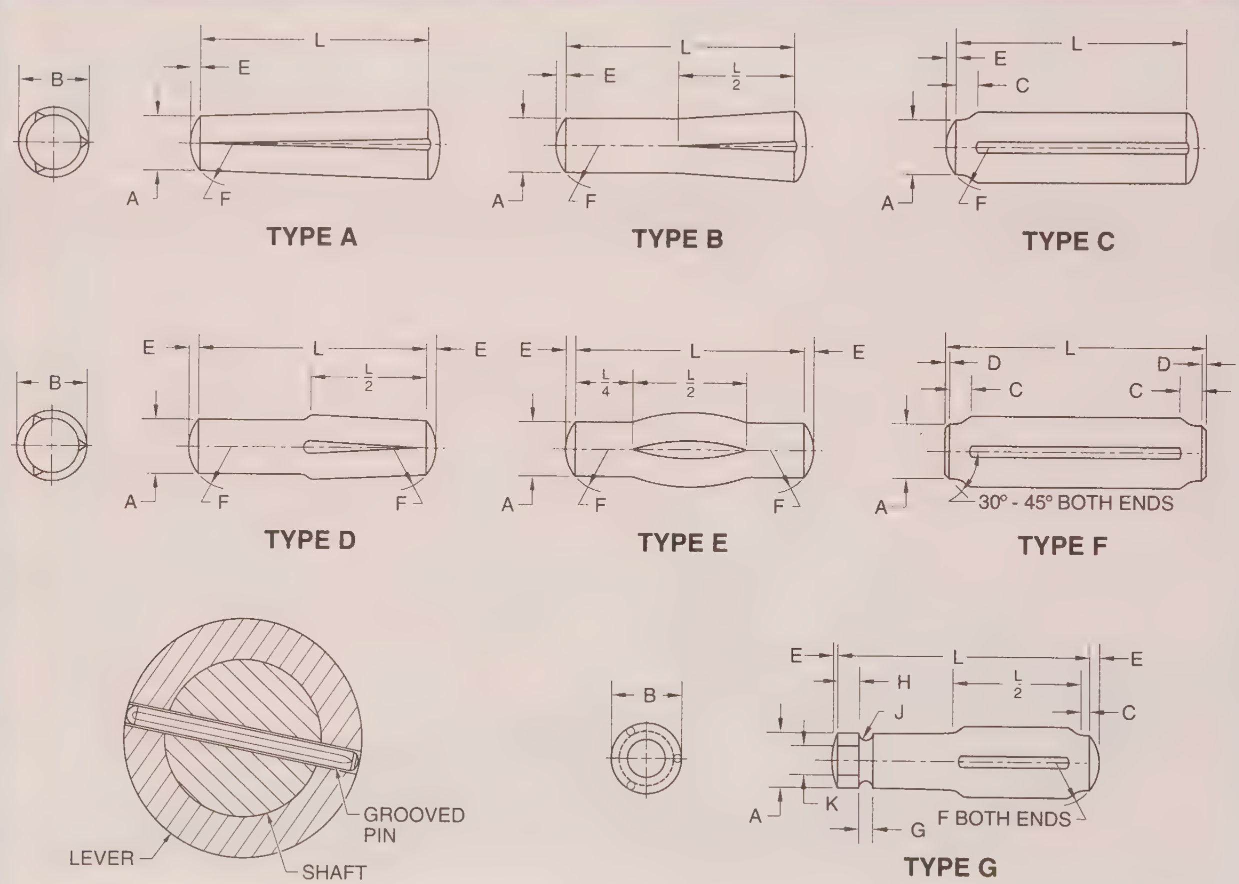
* Diameters 1/16″ through 1/8″, *L* ±0.015. Diameters 5/32″ and 3/16″, *L* ±0.020.

† reference only

GROOVED PINS

Size	Pin Dia *A*		Pilot Length *C*	Pilot Length *D*	Crown Height *E*		Crown Radius *F*		Neck Width *G*		Shoulder Length *H*		Neck Rad *J*	Neck Dia *K*	
Frac	Max	Min	Ref	Min	Max	Min	Max	Min	Max	Min	Max	Min	Ref	Max	Min
1/32	0.0312	0.0302	0.015	—	—	—	—	—	—	—	—	—	—	—	—
3/64	0.0469	0.0459	0.031	—	—	—	—	—	—	—	—	—	—	—	—
1/16	0.0625	0.0615	0.031	0.016	0.0115	0.0015	0.088	0.098	—	—	—	—	—	—	—
5/64	0.0781	0.0771	0.031	0.016	0.0137	0.0037	0.104	0.084	—	—	—	—	—	—	—
3/32	0.0938	0.928	0.031	0.016	0.0141	0.0041	0.135	0.115	0.038	0.028	0.041	0.031	0.016	0.067	0.057
7/64	0.1094	0.1074	0.031	0.016	0.0160	0.0060	0.150	0.130	0.038	0.028	0.041	0.031	0.016	0.082	0.072
1/8	0.1250	0.1230	0.031	0.016	0.0180	0.0080	0.166	0.146	0.069	0.059	0.041	0.031	0.031	0.088	0.078
5/32	0.1563	0.1543	0.062	0.031	0.0220	0.0120	0.198	0.178	0.069	0.059	0.057	0.047	0.031	0.109	0.099
3/16	0.1875	0.1855	0.062	0.031	0.0230	0.0130	0.260	0.240	0.069	0.059	0.057	0.047	0.031	0.130	0.120
7/32	0.2188	0.2168	0.062	0.031	0.0270	0.0170	0.291	0.271	0.101	0.091	0.072	0.062	0.047	0.151	0.141
1/4	0.2500	0.2480	0.062	0.031	0.0310	0.0210	0.322	0.302	0.101	0.091	0.072	0.062	0.047	0.172	0.162
5/16	0.3125	0.3105	0.094	0.047	0.0390	0.0290	0.385	0.365	0.132	0.122	0.104	0.094	0.062	0.214	0.204
3/8	0.3750	0.3730	0.094	0.047	0.0440	0.0340	0.479	0.459	0.132	0.122	0.135	0.125	0.062	0.255	0.245
7/16	0.4375	0.4355	0.094	0.047	0.0520	0.0420	0.541	0.521	0.195	0.185	0.135	0.125	0.094	0.298	0.288
1/2	0.5000	0.4980	0.094	0.047	0.0570	0.0470	0.635	0.615	0.195	0.185	0.135	0.125	0.094	0.317	0.307

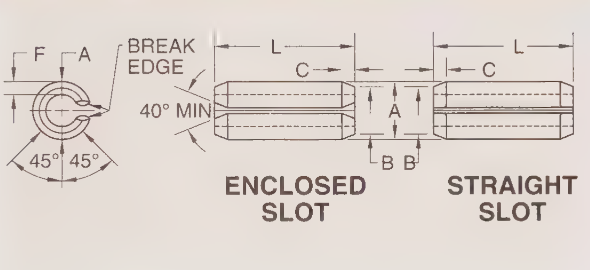
GROOVED PINS



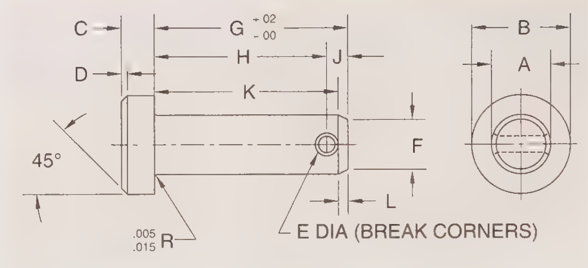
SLOTTED SPRING PINS

Pin Dia		Pin Dia A		Chamfer Dia B	Chamfer Length C		Stock Thickness F	Recommended Hole Size		Material: AISI 1070-1095 and 420	Material: AISI 302	Material: Beryllium Copper
Frac	Deci	Max	Min	Max	Max	Min	Basic	Max	Min	Min Double Shear Load (lb)		
1/16	0.062	0.069	0.066	0.059	0.028	0.007	0.012	0.065	0.062	425	350	270
5/64	0.078	0.086	0.083	0.075	0.032	0.008	0.018	0.081	0.078	650	550	400
3/32	0.094	0.103	0.099	0.091	0.038	0.008	0.022	0.097	0.094	1000	800	660
1/8	0.125	0.135	0.131	0.122	0.044	0.008	0.028	0.129	0.125	2100	1500	1200
9/64	0.141	0.149	0.145	0.137	0.044	0.008	0.028	0.144	0.140	2200	1600	1400
5/32	0.156	0.167	0.162	0.151	0.048	0.010	0.032	0.160	0.156	3000	2000	1800
3/16	0.188	0.199	0.194	0.182	0.055	0.011	0.040	0.192	0.187	4400	2800	2600
7/32	0.219	0.232	0.226	0.214	0.065	0.011	0.048	0.224	0.219	5700	3550	3700
1/4	0.250	0.264	0.258	0.245	0.065	0.012	0.048	0.256	0.250	7700	4600	4500
5/16	0.312	0.328	0.321	0.306	0.080	0.014	0.062	0.318	0.312	11,500	7095	6800
3/8	0.375	0.392	0.385	0.368	0.095	0.016	0.077	0.382	0.375	17,600	10,000	10,100
7/16	0.438	0.456	0.448	0.430	0.095	0.017	0.077	0.445	0.437	20,000	12,000	12,200
1/2	0.500	0.521	0.513	0.485	0.110	0.025	0.094	0.510	0.500	25,800	15,500	16,800
5/8	0.625	0.650	0.640	0.608	0.125	0.030	0.125	0.636	0.625	46,000	18,800	—
3/4	0.750	0.780	0.769	0.730	0.150	0.030	0.150	0.764	0.750	66,000	23,200	—

SLOTTED SPRING PINS



CLEVIS PINS



CLEVIS PINS

Pin Frac	Pin Deci	A Shank Dia Max	A Shank Dia Min	B Head Dia Max	B Head Dia Min	C Head Height Max	C Head Height Min	D Head Chamfer ±0.01	E Hole Dia Max	E Hole Dia Min	F Point Dia Max	F Point Dia Min	G* Pin Length Basic	H Head to Center of Hole Max	H Head to Center of Hole Min	J† End to Center Ref Basic	K‡ Head to Edge of Hole Ref Max	K‡ Head to Edge of Hole Ref Min	L Point Length Max	L Point Length Min	Rec Cotter Pin Nom Size	
3/16	0.188	0.186	0.181	0.32	0.30	0.07	0.05	0.02	0.088	0.073	0.15	0.14	0.58	0.504	0.484	0.09	0.548	0.520	0.055	0.035	1/16	0.062
1/4	0.250	0.248	0.243	0.38	0.36	0.10	0.08	0.03	0.088	0.073	0.21	0.20	0.77	0.692	0.672	0.09	0.736	0.708	0.055	0.035	1/16	0.062
5/16	0.312	0.311	0.306	0.44	0.42	0.10	0.08	0.03	0.119	0.104	0.26	0.25	0.94	0.832	0.812	0.12	0.892	0.864	0.071	0.049	3/32	0.093
3/8	0.375	0.373	0.368	0.51	0.49	0.13	0.11	0.03	0.119	0.104	0.33	0.32	1.06	0.958	0.938	0.12	1.018	0.990	0.071	0.049	3/32	0.093
7/16	0.438	0.436	0.431	0.57	0.55	0.16	0.14	0.04	0.119	0.104	0.39	0.38	1.19	1.082	1.062	0.12	1.142	1.114	0.071	0.049	3/32	0.093
1/2	0.500	0.496	0.491	0.63	0.61	0.16	0.14	0.04	0.151	0.136	0.44	0.43	1.36	1.223	1.203	0.15	1.298	1.271	0.089	0.063	1/8	0.125
5/8	0.625	0.621	0.616	0.82	0.80	0.21	0.19	0.06	0.151	0.136	0.56	0.55	1.61	1.473	1.453	0.15	1.548	1.521	0.089	0.063	1/8	0.125
3/4	0.750	0.746	0.741	0.94	0.92	0.26	0.24	0.07	0.182	0.167	0.68	0.67	1.91	1.739	1.719	0.18	1.830	1.802	0.110	0.076	5/32	0.156
7/8	0.875	0.871	0.866	1.04	1.02	0.32	0.30	0.09	0.182	0.167	0.80	0.79	2.16	1.989	1.969	0.18	2.080	2.052	0.110	0.076	5/32	0.156
1	1.000	0.996	0.991	1.19	1.17	0.35	0.33	0.10	0.182	0.167	0.93	0.92	2.41	2.239	2.219	0.18	2.330	2.302	0.110	0.076	5/32	0.156

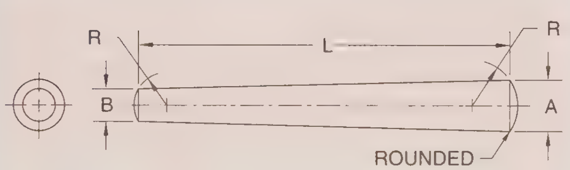
* Lengths tabulated are intended for use with standard clevises without spacers.

† J dimension is for calculating hole location from underside of head on pins of lengths not tabulated.

‡ reference dimension

TAPER PINS									
Pin		Major Dia (Large End) A				End Crown Radius R		Range of Lengths L	
		Commercial Class		Precision Class					
Size #	Dia B	Max	Min	Max	Min	Max	Min	Reamer	Other
7/0	0.0625	0.0638	0.0618	0.0635	0.0625	0.072	0.052	—	¼ - 1
6/0	0.0780	0.0793	0.0773	0.0790	0.0780	0.088	0.068	—	¼ - 1½
5/0	0.0940	0.0953	0.0933	0.0950	0.0940	0.104	0.084	¼ - 1	1¼, 1½
4/0	0.1090	0.1103	0.1083	0.1100	0.1090	0.119	0.099	¼ - 1	1¼ - 2
3/0	0.1250	0.1263	0.1243	0.1260	0.1250	0.135	0.115	¼ - 1	1¼ - 2
2/0	0.1410	0.1423	0.1403	0.1420	0.1410	0.151	0.131	½ - 1¼	1½ - 2½
0	0.1560	0.1573	0.1553	0.1570	0.1560	0.166	0.146	½ - 1¼	1½ - 3
1	0.1720	0.1733	0.1713	0.1730	0.1720	0.182	0.162	¾ - 1¼	1½ - 3
2	0.1930	0.1943	0.1923	0.1940	0.1930	0.203	0.183	¾ - 1½	1¾ - 3
3	0.2190	0.2203	0.2183	0.2200	0.2190	0.229	0.209	¾ - 1¾	2 - 4
4	0.2500	0.2513	0.2493	0.2510	0.2500	0.260	0.240	¾ - 2	2¼ - 4
5	0.2890	0.2903	0.2883	0.2900	0.2890	0.299	0.279	1 - 2½	2¾ - 6
6	0.3410	0.3423	0.3403	0.3420	0.3410	0.351	0.331	1¼ - 3	3¼ - 6
7	0.4090	0.4103	0.4083	0.4100	0.4090	0.419	0.399	1¼ - 3¾	4 - 8
8	0.4920	0.4933	0.4913	0.4930	0.4920	0.502	0.482	1¼ - 4½	4¾ - 8
9	0.5910	0.5923	0.5903	0.5920	0.5910	0.601	0.581	1¼ - 5¼	5½ - 8
10	0.7060	0.7073	0.7053	0.7070	0.7060	0.716	0.696	1½ - 6	6¼ - 8
11	0.8600	0.8613	0.8593	—	—	0.870	0.850	—	2 - 8
12	1.0320	1.0333	1.0313	—	—	1.042	1.022	—	2 - 9
13	1.2410	1.2423	1.2403	—	—	1.251	1.231	—	3 - 11
14	1.5210	1.5223	1.5203	—	—	1.531	1.511	—	3 - 13

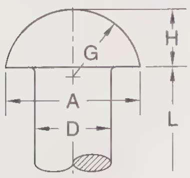
TAPER PINS



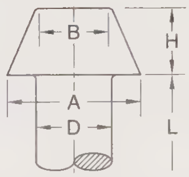
LARGE RIVETS

Head	D		A	H	G
	Body Dia		Hd Dia	Hd Height	Hd Radius
Button	Nom	Max	Max	Max	
	1/2	0.520	0.938	0.406	0.443
	5/8	0.655	1.157	0.500	0.553
	3/4	0.780	1.390	0.593	0.664
	7/8	0.905	1.609	0.687	0.775
	1	1.030	1.828	0.781	0.885
Cone	D		A	B	H
	Body Dia		Major Hd Dia	Minor Hd Dia	Hd Height
	Nom	Max	Max	Max	Max
	1/2	0.520	0.938	0.532	0.469
	5/8	0.655	1.157	0.649	0.578
	3/4	0.780	1.390	0.781	0.687
	7/8	0.905	1.609	0.898	0.797
	1	1.030	1.828	1.016	0.906
Flat-Top Countersunk	D		A	H	Q
	Body Dia		Hd Dia	Hd Depth	Hd Angle*
	Nom	Max	Max	Max	
	1/2	0.520	0.936	0.281	78
	5/8	0.655	1.194	0.343	78
	3/4	0.780	1.421	0.406	78
	7/8	0.905	1.647	0.469	78
	1	1.030	1.873	0.531	78
Pan	D		A	B	H
	Body Dia		Major Hd Dia	Minor Hd Dia	Hd Height
	Nom	Max	Max	Max	Max
	1/2	0.520	0.863	0.563	0.381
	5/8	0.655	1.063	0.688	0.469
	3/4	0.780	1.278	0.828	0.556
	7/8	0.905	1.478	0.953	0.643
	1	1.030	1.678	1.078	0.731

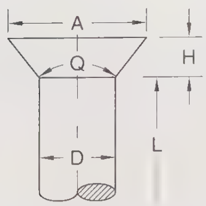
* in degrees



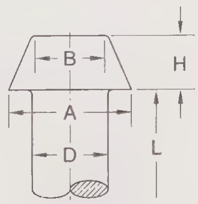
BUTTON HEAD



CONE HEAD



FLAT-TOP COUNTERSUNK HEAD

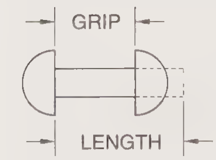


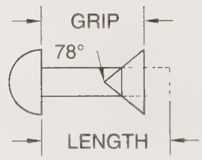
PAN HEAD

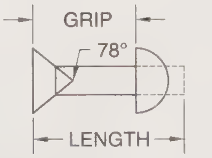
STRUCTURAL RIVETS*

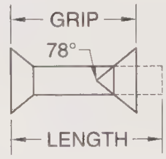
Grip†	Diameter†						
	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4
	Length†						
1/2	1 5/8	1 7/8	1 7/8	2	2 1/8	—	—
5/8	1 3/4	2	2	2 1/8	2 1/4	—	—
3/4	1 7/8	2 1/8	2 1/8	2 1/4	2 3/8	—	—
7/8	2	2 1/4	2 1/4	2 3/8	2 1/2	—	—
1	2 1/4	2 3/8	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8
1 1/8	2 3/8	2 1/2	2 1/2	2 5/8	2 3/4	2 7/8	3
1 1/4	2 1/2	2 5/8	2 5/8	2 3/4	2 7/8	3	3 1/8
1 3/8	2 5/8	2 3/4	2 3/4	2 7/8	3	3 1/8	3 1/4
1 1/2	2 7/8	3	3	3 1/8	3 1/4	3 3/8	3 1/2
1 5/8	3	3 1/8	3 1/8	3 1/4	3 3/8	3 1/2	3 5/8
1 3/4	3 1/8	3 1/4	3 1/4	3 1/2	3 1/2	3 3/4	3 7/8
1 7/8	3 1/4	3 3/8	3 3/8	3 5/8	3 5/8	3 7/8	4
2	3 1/2	3 1/2	3 5/8	3 3/4	3 3/4	4	4 1/8
2 1/8	3 5/8	3 5/8	3 3/4	3 7/8	3 7/8	4 1/8	4 1/4
2 1/4	3 3/4	3 7/8	3 7/8	4	4 1/8	4 1/4	4 3/8
2 3/8	4	4	4	4 1/8	4 1/4	4 3/8	4 1/2
2 1/2	4 1/8	4 1/8	4 1/8	4 1/4	4 3/8	4 1/2	4 5/8
2 5/8	4 1/4	4 1/4	4 1/4	4 3/8	4 1/2	4 5/8	4 3/4
2 3/4	4 3/8	4 3/8	4 3/8	4 1/2	4 5/8	4 3/4	4 7/8
2 7/8	4 5/8	4 5/8	4 5/8	4 5/8	4 3/4	4 7/8	5
	1	1	1 1/8	1 1/4	1 1/4	—	—
	1 1/8	1 1/4	1 1/4	1 3/8	1 3/8	—	—
	1 3/8	1 3/8	1 3/8	1 1/2	1 1/2	—	—
	1 1/2	1 1/2	1 1/2	1 5/8	1 5/8	—	—
	1 5/8	1 5/8	1 5/8	1 3/4	1 3/4	1 7/8	1 7/8
	1 3/4	1 3/4	1 7/8	1 7/8	1 7/8	2	2
	2	2	2	2	2	2 1/8	2 1/8
	2 1/8	2 1/8	2 1/8	2 1/4	2 1/4	2 3/8	2 3/8
	2 1/4	2 1/4	2 1/4	2 3/8	2 3/8	2 1/2	2 1/2
	2 3/8	2 3/8	2 3/8	2 1/2	2 1/2	2 5/8	2 5/8
	2 5/8	2 5/8	2 5/8	2 5/8	2 5/8	2 3/4	2 3/4
	2 3/4	2 3/4	2 3/4	2 3/4	2 3/4	2 7/8	2 7/8
	2 7/8	2 7/8	2 7/8	2 7/8	2 7/8	3	3
	3 1/8	3	3	3	3	3 1/8	3 1/8
	3 1/4	3 1/8	3 1/8	3 1/8	3 1/4	3 1/4	3 1/4
	3 3/8	3 3/8	3 3/8	3 3/8	3 3/8	3 3/8	3 3/8
	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 5/8	3 5/8
	3 3/4	3 5/8	3 5/8	3 5/8	3 5/8	3 3/4	3 3/4
	3 7/8	3 3/4	3 3/4	3 3/4	3 3/4	3 7/8	3 7/8
	4	3 7/8	3 7/8	3 7/8	3 7/8	4	4

* Length of rivets includes amount necessary to form one head.





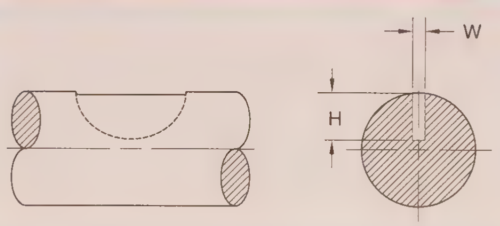




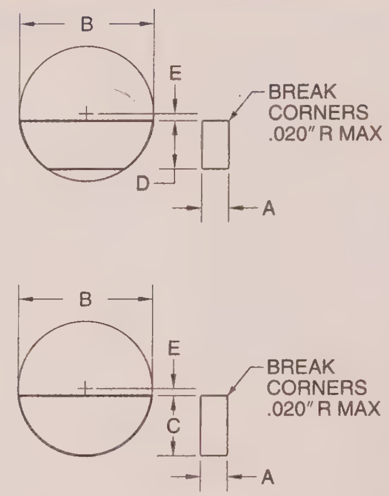
WOODRUFF KEYS AND KEYSEATS

Key No.	Nom Key Size A × B	Key Height C	Key Height D	Dist Below Center E	Keyseat Width W	Keyseat Depth H
		Max	Max			Max.
204	1/16 × 1/2	0.203	0.194	3/64	0.0630	0.1718
304	3/32 × 1/2	0.203	0.194	3/64	0.0943	0.1561
305	3/32 × 1/2	0.250	0.240	1/16	0.0943	0.2031
404	1/8 × 1/2	0.203	0.194	3/64	0.1255	0.1405
405	1/8 × 5/8	0.250	0.240	1/16	0.1255	0.1875
406	1/8 × 3/4	0.313	0.303	1/16	0.1255	0.2505
505	5/32 × 5/8	0.250	0.240	1/16	0.1568	0.1719
506	5/32 × 3/4	0.313	0.303	1/16	0.1568	0.2349
507	5/32 × 7/8	0.375	0.365	1/16	0.1568	0.2969
606	3/16 × 3/4	0.313	0.303	1/16	0.1880	0.2193
607	3/16 × 7/8	0.375	0.365	1/16	0.1880	0.2813
608	3/16 × 1	0.438	0.428	1/16	0.1880	0.3443
609	3/16 × 1 1/8	0.484	0.475	5/64	0.1880	0.3903
807	1/4 × 7/8	0.375	0.365	1/16	0.2505	0.2500
808	1/4 × 1	0.438	0.428	1/16	0.2505	0.3130
809	1/4 × 1 1/8	0.484	0.475	5/64	0.2505	0.3590
810	1/4 × 1 1/4	0.547	0.537	5/64	0.2505	0.4220
811	1/4 × 1 3/8	0.594	0.584	3/32	0.2505	0.4690
812	1/4 × 1 1/2	0.641	0.631	7/64	0.2505	0.5160
1008	5/16 × 1	0.438	0.428	1/16	0.3130	0.2818
1009	5/16 × 1 1/8	0.484	0.475	5/64	0.3130	0.3278
1010	5/16 × 1 1/4	0.547	0.537	5/64	0.3130	0.3908
1011	5/16 × 1 3/8	0.594	0.584	3/32	0.3130	0.4378
1012	5/16 × 1 1/2	0.641	0.631	7/64	0.3130	0.4848
1210	3/8 × 1 1/4	0.547	0.537	5/64	0.3755	0.3595
1211	3/8 × 1 3/8	0.594	0.584	3/32	0.3755	0.4065
1212	3/8 × 1 1/2	0.641	0.631	7/64	0.3755	0.4535

KEYSEATS



KEYS



WOODRUFF

SQUARE AND FLAT STOCK KEY SIZES

Shaft Dia	Square Key Sizes	Flat Key Sizes
1/2 - 9/16	1/8	1/8 × 3/32
5/8 - 7/8	3/16	3/16 × 1/8
15/16 - 1 1/4	1/4	1/4 × 3/16
1 5/16 - 1 3/8	5/16	5/16 × 1/4
1 7/16 - 1 3/4	3/8	3/8 × 1/4
1 13/16 - 2 1/4	1/2	1/2 × 3/8
2 5/16 - 2 3/4	5/8	5/8 × 7/16
2 7/8 - 3 1/4	3/4	3/4 × 1/2

Glossary

A

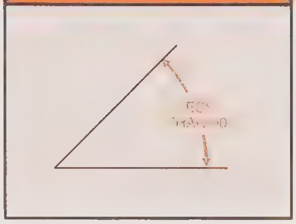
A, B, and C codes: Numerical control codes used to specify rotation around one of the primary axes. See *numerical control.*

abbreviation: A shortened version of the letters forming a word.

absolute programming: A method of numerical control where each movement is taken from the origin. See *numerical control.*

acute angle: An angle that contains less than 180°. See *angle.*

ACUTE ANGLE



acute triangle: A scalene triangle with each angle less than 90°. See *scalene triangle.*

addendum: Portion of the gear teeth between the pitch circle and the addendum circle. See *pitch circle* and *addendum circle.*

addendum circle: Circle formed by tops of gear teeth.

addition: The process of uniting two or more numbers to make one number.

aligned section: A sectional view in which the cutting plane line is bent to pass through detailed features and the sectional view is revolved. See *cutting plane line* and *sectional view.*

allowance: The difference between the design size and the basic size of a thread.

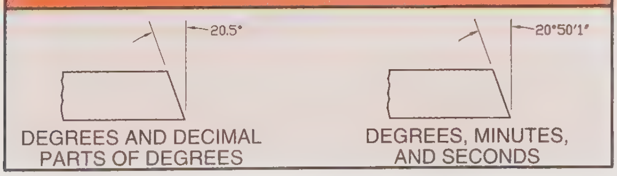
alloy: A metal that consists of more than one chemical element, with at least one of the elements being a pure metal.

altitude: The perpendicular distance from the vertex to the base of a pyramid. The perpendicular distance between the two bases of a cone. See *vertex.*

angle: The intersection of two lines or surfaces.

angular dimension: A dimension that measures angles. They are commonly expressed as degrees and decimal parts of a degree, or as degrees, minutes, and seconds.

ANGULAR DIMENSION



annealing: The process of heating metal and allowing it to cool very slowly.

Arabic numerals: Numbers expressed by the ten digits 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9.

arc: A portion of the circumference. See *circumference.*

area: The number of unit squares equal to the surface of an object.

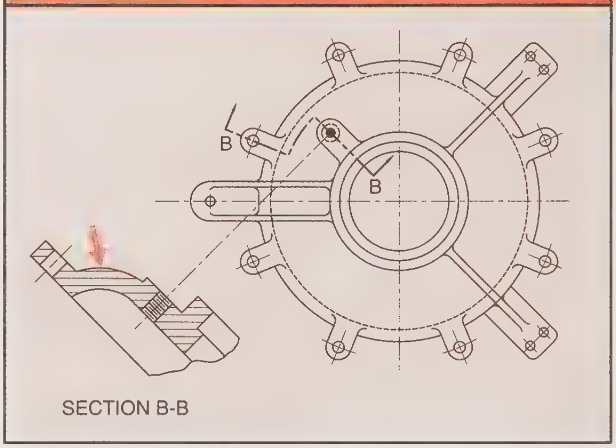
arrowhead: A symbol that indicates the extent of a dimension.

assembly prints: Prints that show how two or more parts fit together.

asymmetrical object: An object in which one half is not the mirror image of the other half.

auxiliary section: A sectional view that is not one of the principal planes. See *sectional view.*

AUXILIARY SECTION



axonometric: A pictorial drawing showing three sides of an object with horizontal and vertical dimensions drawn to scale and containing no true view of any side.

B

backlash: Amount of movement or play between meshing teeth of gears.

back (transverse) pitch: The distance from the center of one row of rivets to the center of the adjacent row of rivets.

base: The side upon which a triangle stands. See *triangle.*

base circle (cam): Circle formed at the radius of the cam drop.

base circle (spur gear): Circle from which an involute tooth curve is generated or developed. See *involute.*

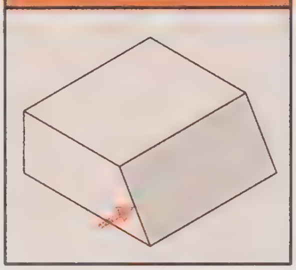
bases: The ends of a prism. See *prism.*

basic dimension: A numeric value used to describe a theoretical exact size, shape, or location of a feature.

bending: Process in which a material is uniformly stretched around a straight axis.

bevel: A sloped edge of an object running from surface to surface. See *chamfer.*

BEVEL



bevel gears: Spur gears with tapered teeth used in applications where shaft axes are not parallel and intersect. See *spur gears.*

blind hole: A drilled hole that does not pass through the material.

blind rivet: A rivet with a hollow shank that joins two parts with access from one side only. See *rivet.*

blunt start: The removal of the partial thread at the entering end of a thread.

boring: Process of enlarging an existing hole or shape to specifications with a cutting tool.

boss: A short projection with a finished surface which extends above the surface of a part.

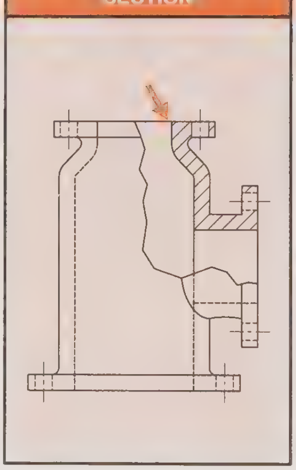
break line: A line that can show internal features or avoid showing continuous features.

breakout side: A stamped part in the side opposite the die that breaks through the surfaces.

brittleness: Lack of ductility in a material. See *ductility.*

broken-out section: A sectional view in which a small portion designated by a freehand break line is removed. The partial section view appears to have been broken out of the object. See *sectional view.*

BROKEN-OUT SECTION



C

cabinet: An oblique drawing with receding lines drawn to one-half the scale of lines in the true view. See *oblique.*

cam: Machine part that transmits motion using an irregular external or internal surface.

cam displacement: Maximum travel distance from the lowest to the highest point of a cam. See *cam.*

cam follower: Machine part in contact with the cam which moves in a designated path. See *cam.*

cam profile: Actual shape or irregular surface features which actuate the cam follower.

carburizing: Case hardening process in which carbon is introduced into a solid iron-base alloy heated above a certain temperature. See *case hardening.*

Cartesian coordinate system: A system of locating points in space defined by perpendicular planes.

case hardening: Process of increasing the hardness of a metal surface without changing the mechanical properties of the core.

casting: Process of pouring molten material into a mold to form a part.

cast iron: Alloy of iron and carbon containing 1.70% to 4.50% carbon. See *alloy.*

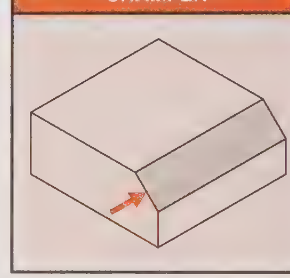
cavalier: An oblique drawing with receding lines drawn to the same scale as the lines in the true view. See *oblique.*

center lines: Lines that locate the centerpoints of arcs and circles. Drawn as a series of long and short dashes.

central processing unit (CPU): The control center of a computer.

chamfer: A sloped edge of an object running from surface to side. See *bevel.*

CHAMFER



chemical properties: Properties of a material pertaining to chemical reactivity and the surrounding area.

chord: A line from circumference to circumference not through the centerpoint.

chordal thickness: Thickness of a tooth measured along the pitch circle. See *pitch circle.*

circle: A plane figure generated around a centerpoint. It is formed by a cutting plane perpendicular to the axis of a cone. See *plane figure.*

circular pitch: Distance between the centers of two adjacent teeth on the pitch circle. See *pitch circle.*

circumference: 3.1416 times the diameter of a circle. See *diameter* and *circle.*

clearance: Space between the bottom of the tooth space and tip of a tooth fully meshed into that tooth space.

clearance requirements: Specifications of the servicing and functional space required for the piece of equipment.

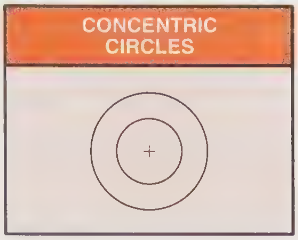
coefficient of thermal expansion: Unit change in the length of a material caused by changing the temperature 1°F.

complementary angles: Two angles that equal 90°. See *angle*.

complete (full) thread: The part of a thread having full form at both crest and root. See *screw thread*, *crest*, and *root*.

composite drawing: Drawing that shows the forging detail using phantom lines and the machining detail using object lines.

computer-aided design (CAD): The generation and reproduction of line drawings and prints with computers.



concentric circles: Circles having different diameters and the same centerpoint. See *circle*.

cone: A solid figure generated by a straight line moving in contact with a curve and passing through the vertex. See *vertex*.

conic section: A curve produced by a plane intersecting a right circular cone. See *right circular cone*.

constant pitch: A standard screw thread series with a set number of threads per inch regardless of diameter.

constant-velocity motion: Provides a uniform, consistent rise to fall motion at a constant rate of speed during one revolution.

conventional break: A standard method of showing shortened views of elongated objects.

conventional drafting practices: A language of standard lines, symbols, and abbreviations used in conjunction with drafting principles so that drawings are consistent and easy to read.

conventional views: Orthographic views used to show exterior features of an assembly.

conventional violation: Acceptable method of showing a feature although other standards may be violated.

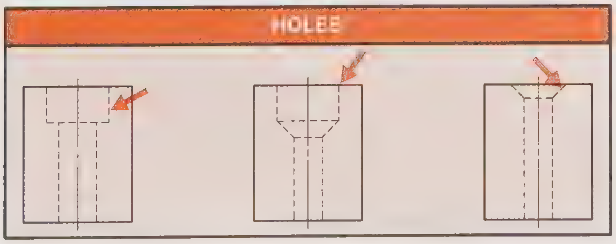
corners: Angular spaces at the intersection of surfaces.

counterbored hole: An enlarged and recessed hole with square shoulders.

counterdrilled hole: A hole with a cone-shaped opening below the outer surface.

countersink: The tool that produces a countersunk hole.

countersunk hole: A hole with a cone-shaped opening or recess at the outer surface.



crest: The surface that joins the flanks of the thread and is farthest from the cylinder or cone from which the thread projects.

crest clearance: In a thread assembly, the distance, measured perpendicular to the axis, between the crest of a thread and the root of its mating thread.

cubic inch: A unit of volume measurement 1″ × 1″ × 1″ or its equivalent.

cubic foot: A unit of volume measurement containing 1728 cu in. (12″ × 12″ × 12″ = 1728 cu in.).

cursor: The solid or flashing pointer of a computer indicating position of work.

cutting plane line: A line that shows where an object is imagined to be cut in order to view internal features.

cutting speed: Speed or motion of the cutting tool in the machining operation.

cylinder: A solid generated by a straight line (genatrix) moving in contact with a curve and remaining parallel to the axis and its previous position.

D

datum: A point, line, axis, or surface which serves as the origin for dimensions.

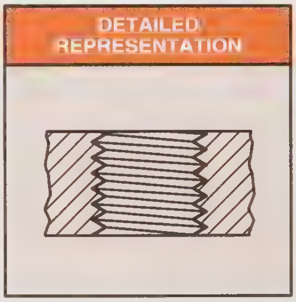
decimal: A fraction with a denominator of 10, 100, 1000, etc.

decimal point: The period in a decimal number.

dedendum: Portion of the gear teeth which extends below the pitch circle. See *pitch circle*.

denominator: The lower number of a fraction that shows how many parts the whole number has been divided into. See *fraction*.

depth of cut: Penetration of the cutting tool for each pass expressed in inches or millimeters.



detailed representation: A method of thread representation in which the thread profiles are connected by helices. See *helix*.

detail prints: Prints that provide complete information needed to produce a part.

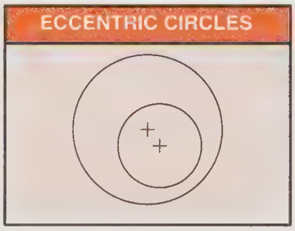
diagonal pitch: The distance between the centers of rivets nearest each other in adjacent rows. See *rivet*.

diameter: The distance from circumference (outside) to circumference of a circle through the centerpoint.

diametral pitch: Ratio of the number of teeth to the number of inches of pitch diameter. See *pitch diameter*.

dimension lines: Thin lines that are used with dimensions to show size or location.
dimensions: Numerical values that give size, form, or location of objects.
dimetric: An axonometric drawing with two axes drawn on equal angles and one axis containing either fewer or more degrees. See *axonometric*.
dividend: The number to be divided.
division: The process of finding how many times one number contains the other number.
divisor: The number by which division is done.
dodecahedron: A regular solid of twelve pentagons. See *pentagon*.
drawing: Process of pulling material through a die to shape the part to final size and shape.
drilling: Cutting of round holes in material with a drill.
ductile: Having the ability to be formed easily.
ductility: Ability of a material to stretch, bend, or twist without breaking or cracking.
dwell: Time during a cam revolution in which there is no motion by the cam follower. See *cam follower*.

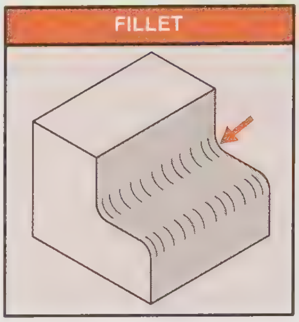
E



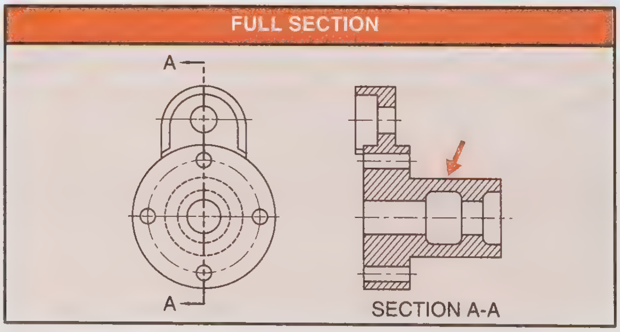
eccentric circles: Circles with different diameters and different centerpoints. See *circle*.
edge: The intersection of two surfaces.
ellipse: A plane curve with two focal points. A plane figure formed by a cutting plane oblique to the axis of a cone, but at a greater angle with the axis than with the elements of the cone.
equation: A means of showing that two numbers or two groups of numbers are equal to the same amount.
equilateral triangle: A triangle that has three equal angles and three equal sides. See *triangle*.
even number: Any number that can be divided by 2 an exact number of times. For example, 8 is an even number.
extension line: Line that extends from surface features and terminates dimension lines.
external thread: A thread on the external surface of a cylinder or cone.
extruding: Process of pushing material through a die to obtain the desired shape.

F

feature: Any surface, angle, hole, etc. which may be controlled on a part.
feature information: Any information required for installation of equipment.
feed: Rate at which the cutting tool advances in relation to the cutting tool motion.
ferrous metal: Metal that has iron as the major alloying element. See *alloy*.



field rivet: Rivet placed in the field. See *rivet*.
fillet: A rounded interior (internal) corner.
flame hardening: Heating of a metal surface with a torch followed by quenching to obtain the proper hardness.
flank (side): On a thread, either surface connecting the crest with the root, the intersection of which with an axial plane is a straight line.
foreshortening: The apparent shortening of particular parts.
forging: Process of forming a metal part with pressure or hammering.
forging print: Print that describes the elements forged into a part.
form: A thread's profile in an axial plane for a length of one pitch. See *pitch*.
formula: A mathematical equation which contains a fact, rule, or principle. See *equation*.
fraction: One part of a whole number.
fractional dimensions: Dimensions that are expressed as inches and fractional parts of an inch.
front auxiliary view: A primary auxiliary view that has the inclined surface perpendicular to the frontal plane and is hinged to the frontal plane. See *primary auxiliary view*.
frustum: The remaining portion of a pyramid or cone with a cutting plane passed parallel to the base.
full section: A sectional view in which the cutting plane passes entirely through the object.

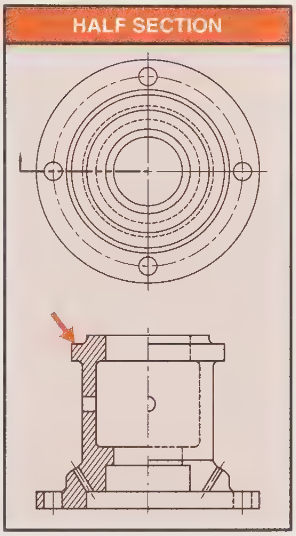


function key: A computer key that performs a particular function when depressed.

G

G codes: Numerical control codes for preparatory commands used to set up the machine for a specific operation.
gear: Toothed wheel used in pairs to transmit power or motion from one shaft to another.
geometric dimensioning and tolerancing: A method of specifying the allowable variations from an exact part.
graded pitch: A standard screw thread series with a different number of threads per inch based on the diameter. See *screw thread series*.
great circle: The circle formed by passing a cutting plane through the center of a sphere. See *circle* and *sphere*.
grinding: The process of removing material using an abrasive wheel mounted on a rotating horizontal or vertical arbor.
grip: The effective holding length of a rivet. See *rivet*.
grooves: Machined internal or external sections of a part.

H



half section: A sectional view in which two cutting planes are passed at right angles to each other along the center lines or symmetrical axes. See *sectional view*.
hardening: Process of heating metal followed by quenching in oil, water, or other cooling medium.
hardness: The ability of a material to resist indentation.
hardware: The physical components of a computer system, including the input devices, central processing unit (CPU), and output devices.
harmonic motion: Constant velocity without consistency in motion.
heat treatment: Application of heat to change the properties of a metal without changing its size and shape.
helical gears: Spur gears with teeth not parallel to the shaft axes. See *spur gears*.
helix: The curve traced on a cylinder or cone by a point rotating at a right angle to the axis.
heptagon: A plane figure with seven sides.
herringbone gears: Gears with two rows of helical teeth.
hexahedron: A regular solid of six squares.
hexagon: A plane figure with six sides.
hidden line: Line that represents shapes which cannot be seen. Drawn with a series of short dashes.
horizontal: Parallel to the horizon; level.
horizontal line: A line parallel to the horizon.
hyperbola: A plane figure formed by a cutting plane that has a smaller angle with the axis than with the elements of the cone.
hypotenuse: The side of a right triangle opposite the right angle. See *right triangle* and *right angle*.

I

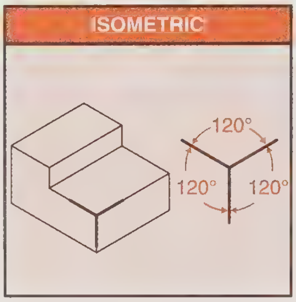
icosahedron: A regular solid of twenty triangles.
improper fraction: A fraction with a numerator larger than its denominator. See *fraction*, *numerator*, and *denominator*.
inclined (slanted) line: A line that is neither horizontal nor vertical. See *horizontal* and *vertical*.
inclined surface: A plane surface perpendicular to one plane of projection and inclined to the remaining two orthographic views.
included angle (angle of thread): The angle between the flanks of the thread measured in an axial plane.
incomplete (vanish or washout) thread: On straight threads, the portion at the end having roots not fully formed by the lead or chamfer on threading tools.
incremental programming: A method of numerical control where each movement originates at the last point where the machine stopped. See *numerical control*.
individual features: Features that are applied to a specific element of a part.
induction hardening: Case hardening a metal surface using electromagnetic induction.
input devices: Hardware used to enter information into a computer system.
installation prints: Prints that outline the general configuration and information needed to install a piece of equipment.
internal thread: A thread on the internal surface of a hollow cylinder or cone.
intersecting surfaces: One surface that meets another surface.
involute: Curve formed by the path of a point on a straight line as it rolls along a convex surface.
irregular plane figure: A plane figure that does not have equal angles and equal sides. See *plane figure*.

irregular polygon: A polygon with unequal sides and unequal angles. See *polygon*.

irregular polyhedra: Polyhedra with faces that are irregular polygons. See *polyhedra* and *polygon*.

isometric: An axonometric drawing with the axes drawn 120° apart. See *axonometric*.

isosceles triangle: A triangle that contains two equal angles and two equal sides. See *triangle*.

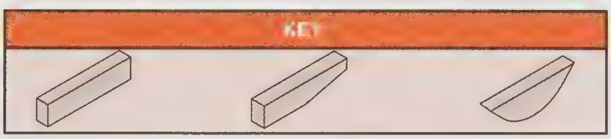


J

joystick: An electromechanical device used to control the cursor on the display screen and enter information into the computer. See *cursor*.

K

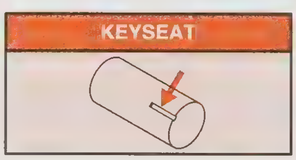
key: Removable part which provides a positive means of transmitting torque between a shaft and a hub when mounted in a keyseat. See *torque* and *keyseat*.



keyboard: An electronic device that sends signals to a computer's CPU. See *central processing unit*.

keyseat: A machined, rectangular groove along the axis of a shaft or hub which mates with a key.

knurl: Raised pattern formed in a material.



L

land: Flat surface on top of the tooth (top land) or the flat surface of the gear between adjacent teeth.

large rivet: Rivet with a shank of ½″ or greater in diameter. See *rivet*.

lead: The distance a threaded part moves axially, with respect to a fixed mating part, in one complete rotation.

leader: Line that connects a dimension, note, or specification with a particular feature of the drawn object.

least material condition (LMC): The minimum amount of material permitted by the tolerance zone.

left-hand thread: A thread, when viewed axially, that winds in a counterclockwise and receding direction.

length of thread engagement: The distance between the extreme points of contact on the pitch cylinders or cones of two mating threads measured parallel to the axis.

light pen: A photosensitive electronic device used to enter data into a computer.

linear dimensions: Dimensions that measure lines and are commonly expressed as decimal inches or millimeters.

linetype library: A CAD file that contains dashed, hidden, center, phantom, dot, dotdash, border, and divide lines. See *computer-aided design*.

lobe: Projecting part or parts of a cam which causes the cam follower to be displaced. See *cam*.

location: A tolerance that refers to the position of one feature in relation to one or more datum features.

lowest common denominator (LCD): The highest number that will divide equally into the denominator and numerator of a fraction. See *denominator* and *numerator*.

M

M codes: Numerical control codes that control the machine actions. See *numerical control*.

machinability: Ease or difficulty with which a material can be machined.

machinability rating number: Used to indicate the machinability of a material. See *machinability*.

machining: Process of removing material from a part to the required specifications.

machining print: Print that shows the machining information required to produce a part.

major diameter: On a straight thread, the diameter of the imaginary coaxial cylinder which bounds the crest of an external thread or the root of an internal thread. On a taper thread at a given position on the thread axis, the diameter of the major cone.

malleability: Ability of a material to be deformed by compressive forces without developing defects.

margin: The distance from the edge of the plate to the center line of the nearest row of rivets.

matte finish: A dull finish that will accept and hold pencil and ink lines well.

maximum material condition (MMC): The maximum amount of material permitted by the tolerance zone.

mechanical properties: Properties of a material under applied loads.

metal: Material consisting of one or more chemical elements having a crystalline structure, high thermal and electrical conductivity, the ability to be deformed when heated, and high reflectivity.

milling: Combines the rotation of the cutting tool and the feeding of the work into the path of the cutter.

millions period: The third period (1,000,000 through 999,999,999). See *period*.

minor diameter: On a straight thread, the diameter of the imaginary co-axial cylinder which bounds the root of an external thread or the crest of an internal thread. On a taper thread at a given position on the thread axis, the diameter of the minor cone at that position.

minuend: The number from which a subtraction is made.

miter gears: Meshing bevel gears having the same number of teeth.

mixed number: A combination of a whole number and a fraction. See *whole number* and *fraction.*

modifiers: Symbols that convey specific information needed to clarify some aspect of a feature.

monitor: A video display terminal used with a computer.

mounting dimensions: Dimensions used to locate holes or threads for screws, studs, brackets, or clips.

mouse: An electronic device used to input information into a computer.

multiple thread: A thread in which the lead is an integral multiple of the pitch. See *lead.*

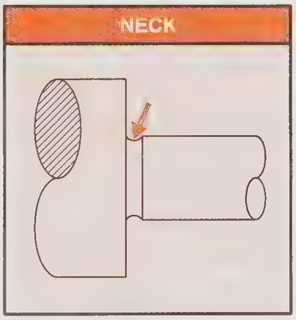
multiplicand: The number which is multiplied.

multiplication: The process of adding one number as many times as there are units in the other number.

multiplier: The number by which multiplication is done. See *multiplication.*

N

neck: Recess cut into a cylindrical part to provide a space between where one diameter changes to another diameter on a cylinder.



nonferrous metals: Metals that do not contain iron and are not magnetic.

non-threaded fasteners: Devices that join or fasten parts together without threads.

normal surface: A plane surface parallel to a plane of projection.

numerator: The upper number of a fraction that shows the number of parts in the fraction.

numerical control: A process of controlling the motion of machine tools using a set of programmed commands.

O

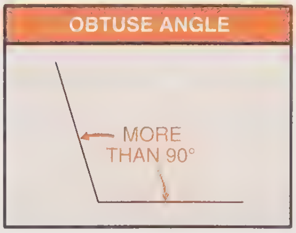
object line: Line that defines the visible shape of an object.

oblique: A pictorial drawing that shows one surface of an object as a true view. A skewed plane or line.

oblique cylinder: A cylinder with the axis not perpendicular to the base. See *cylinder.*

oblique prism: A prism with lateral faces not perpendicular to the bases. See *prism.*

oblique surface: A plane surface not parallel to any plane of projection.



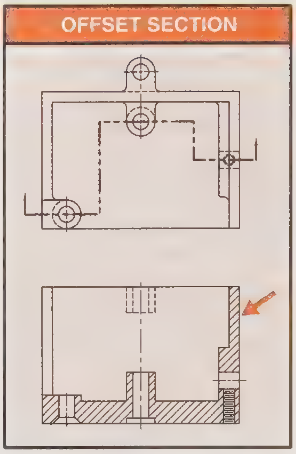
obtuse angle: An angle that contains more than 90°. See *angle.*

obtuse triangle: A scalene triangle with one angle greater than 90°. See *scalene triangle.*

octagon: A plane figure with eight sides.

octahedron: A regular solid of eight triangles.

odd number: Any number that cannot be divided by 2 an exact number of times. For example, 7 is an odd number.



offset section: A sectional view in which the direction of the cutting plane line changes direction from along the main axis to include features which are not located in a straight line.

orientation: A tolerance that refers to the relationship between lines and surfaces.

orthographic assembly prints: Representations of parts shown in one or more of the primary planes of projection.

orthographic projection (multiview drawing): Drawing at right angles.

outline dimension: Dimension that indicates the minimum space required to install a piece of equipment.

output device: Computer hardware that either displays or generates type or drawings.

outside diameter: Equal to the pitch diameter plus twice the addendum. See *addendum.*

P

parabola: A plane figure formed by a cutting plane oblique to the axis and parallel to the elements of the cone. See *oblique.*

parabolic motion: Provides very smooth motion using a parabolic curve.

parallelepiped: A prism with bases that are parallelograms. See *prism* and *parallelogram.*
parallel lines: Lines that remain the same distance apart.
parallelogram: A four-sided plane figure with opposite sides parallel and equal.
patternmaking print: Print that details the information needed to make a pattern for a cast part.
pentagon: A plane figure with five sides.
period: A group of three digits separated from other periods by a comma.
perpendicular: Meeting at a 90° angle.
physical properties: Thermal, electrical, optical, magnetic, and general properties of a material.
pictorial assembly print: Print that shows an assembled part as it appears in three dimensions.
pin: Cylindrical, non-threaded fastener that is placed into a hole to secure the position of two or more parts.
pitch: The distance, measured parallel to the thread's axis, between corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis.
pitch circle: Imaginary circle located approximately halfway between the tops and the roots of the teeth.
pitch diameter: Diameter of the pitch circle. See *pitch circle.*
pitch diameter (simple effective diameter): On a straight thread, the diameter of the imaginary co-axial cylinder, the surface of which would pass through the thread profiles at such points as to make the width of the groove equal to one-half of the basic pitch. On a taper thread at a given position on the thread axis, the diameter of the pitch cone at that position.
plane figure: A flat figure.
plotter: A computer output device that generates finished drawings with pens. See *output device.*
plumb: An exact verticality (determined by a plumb bob and line) with Earth's gravity.
polygon: A many-sided plane figure.
polyhedra: Any solid figure bound by plane surfaces (faces).
primary auxiliary view: A view which is projected to a plane that is perpendicular to one of the three principal planes and inclined to the other two.
prime number: Any number that can be divided an exact number of times only by itself and the number 1.
print: A reproduction of a working drawing. See *working drawing.*
prism: A solid with two bases that are parallel and identical polygons. See *polygon.*
product: The result of multiplication.
proper fraction: A fraction with a denominator larger than its numerator. See *fraction*, *denominator*, and *numerator.*
pure metal: Metal that consists of one chemical element.
pyramid: A solid figure with a base that is a polygon and sides that are triangles. See *polygon* and *triangle.*
Pythagorean Theorem: The square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides. See *hypotenuse* and *right triangle.*

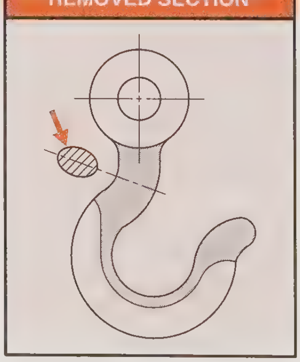
Q

quadrant: One-fourth of a circle. See *circle.*
quadrilateral: A four-sided polygon with four interior angles. See *polygon.*
quotient: The result of division.

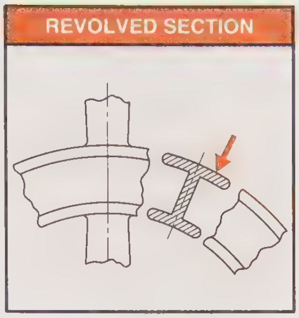
R

rack: Spur gear that is flat rather than concentric. See *spur gear.*
radius: One-half the length of the diameter. See *diameter.*
reaming: A boring operation which enlarges a hole to improve its surface quality.
recess: A groove cut into the internal diameter of a cylinder.
reciprocal: Inversely related (opposite).
rectangle: A quadrilateral with opposite sides equal and four 90° angles. See *quadrilateral.*
rectangular parallelepiped: A prism with bases and faces that are all rectangles. See *prism* and *rectangle.*
regardless of feature size (RFS): Indicates that all positioned tolerances must be met regardless of where the feature lies within the tolerance zone.
regular plane figure: A plane figure that has equal angles and equal sides. See *plane figure.*
regular polygon: A polygon that has equal sides and equal angles. See *polygon.*
regular pyramid: A pyramid with a base that is a regular polygon and a vertex that is perpendicular to the center of the base. See *pyramid.*
regular solids: Polyhedra with faces that are regular polygons (equal sides). See *polyhedra* and *polygon.*
related features: Features that are applied to describe how one feature relates to specific datum or datums. See *datum.*
remainder: The part of the quotient left over whenever the quotient is not a whole number. See quotient and whole number.
removed section: A sectional view that is detached from the projected view and located elsewhere on the sheet. See *sectional view.*

REMOVED SECTION



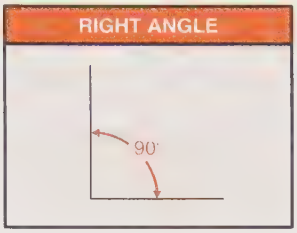
revolved section: A sectional view that shows the cross-sectional shape of elongated objects. See *sectional view.*



rhomboid: A quadrilateral with opposite sides equal and no 90° angles. See *quadrilateral.*

rhombus: A quadrilateral with all sides equal and no 90° angles. See *quadrilateral.*

right angle: An angle that contains 90°. See *angle.*



right circular cone: A cone with the axis at a 90° angle to the circular base. See *cone.*

right cylinder: A cylinder with the axis perpendicular to the base. See *cylinder.*

right-hand thread: A thread, when viewed axially, that winds in a clockwise and receding direction.

right parallelepiped: A prism with all edges perpendicular to the bases. See *prism.*

right prism: A prism with lateral faces perpendicular to the bases. See *prism.*

right triangle: A triangle that contains one 90° angle and no equal sides. See *triangle.*

rivet: A cylindrical metal pin with a preformed head.

rivet pitch: The distance from the center of one rivet to the center of the next rivet in the same row. See *rivet.*

rolling: Process of squeezing material between two revolving rolls to obtain the desired part thickness.

Roman numerals: Numbers expressed by the letters I, X, L, C, D, and M.

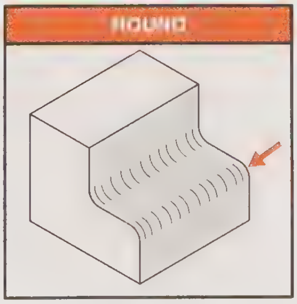
root: The surface that joins the flanks of adjacent thread forms and is identical in position with, or immediately adjacent to, the cylinder or cone from which the thread projects.

root circle: Circle formed by the bottom of the tooth spaces.

root diameter: Diameter of the root circle. See *root circle.*

round: A rounded exterior corner.

runout: **1.** The curve produced by a plane surface tangent to a cylindrical surface. See *tangent.* **2.** Line which indicates the location of a round or fillet at intersecting surfaces. See *round* and *fillet.*



S

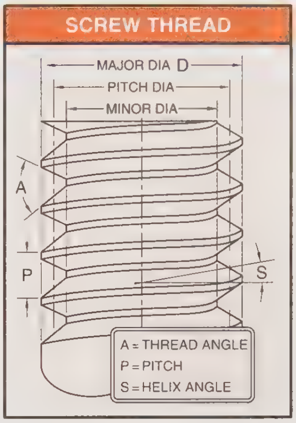
S codes: Numerical control codes used to specify spindle speed.

scalene triangle: A triangle that has no equal angles or equal sides. See *triangle.*

schematic assembly print: Print that shows equipment installation in pictorial or plan view.

schematic representation: A method of thread representation in which solid lines perpendicular to the axis represent roots and crests.

screw thread: A ridge of uniform section in the form of a helix on the internal or external surface of a cylinder, or in the form of a conical spiral on the internal or external surface of a cone or frustum of a cone. See *helix.*

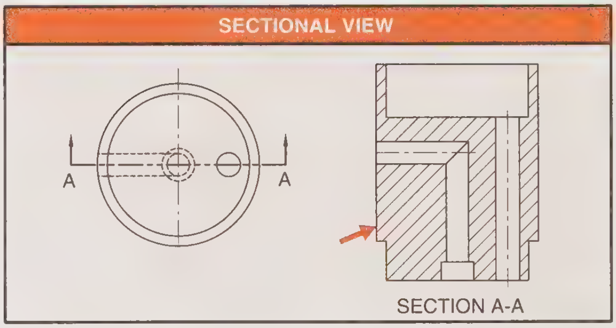


screw thread series: Groups of diameter-pitch combinations.

secant: A straight line touching the circumference at two points. See *circumference.*

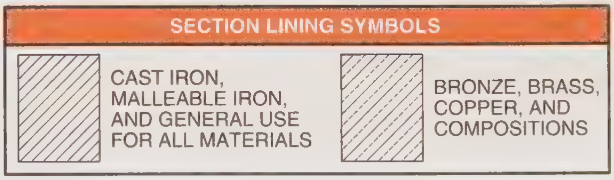
secondary (double) auxiliary view: A view which is projected to a plane that is oblique to all of the principal planes.

sectional view: The interior view of an object through which a cutting plane has been passed.

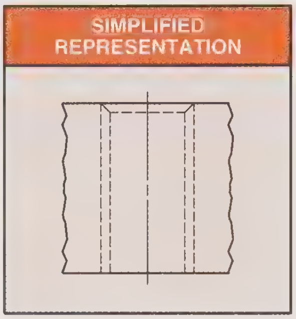


section lining (lines): A series of thin, even-spaced, diagonal lines that show the surfaces through which a cutting plane has passed.

section lining symbols: Standard line conventions that show materials.



sector: A pie-shaped piece of a circle. See *circle*.
segment: The portion of a circle set off by a chord. See *circle* and *chord*.
semicircle: One-half of a circle. See *circle*.
shank: The cylindrical body of a rivet. See *rivet*.
shaping: Cutting operation performed by the reciprocating motion of the cutting tool on a shaper.
shop rivet: A rivet placed in the shop. See *rivet*.
side auxiliary view: A primary auxiliary view that has the inclined surface perpendicular to the side plane and is hinged to the side plane. See *primary auxiliary view*.
simplified representation: A method of thread representation in which hidden lines are drawn parallel to the axis at the approximate depth of the thread. See *thread representation*.



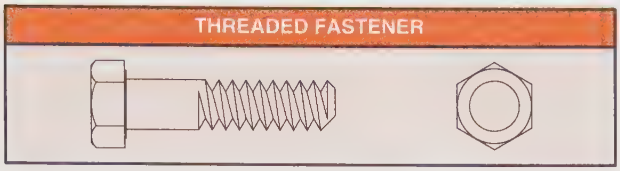
single thread: A thread with the lead equal to the pitch.
sketching: Drawing without instruments.
slant height: The distance from the base to the vertex parallel to a side. See *vertex*.
slot: Elongated hole or rectangle machined into a part.
small circle: The circle formed by passing a cutting plane through a sphere but not through the center. See *circle* and *sphere*.
small rivet: A rivet with a shank of $7/16''$ or less in diameter.
software: The operating system of a computer, on magnetic tape or disks, that provides operational instructions for capturing and formatting keystrokes and generating lines.
special series: A screw thread series with combinations of diameter and pitch not in the standard screw thread series. See *screw thread series*.
sphere: A solid figure generated by a circle revolving about one of its axes. See *circle*.
spinning: Process of drawing material into the specified shape with pressure on the material as it rotates.
spiral bevel gears: Bevel gears that have curved teeth which provide smoother operation at high speeds. See *bevel gears*.
splines: Series of teeth or parallel surfaces machined into a shaft (external splines) or hub (internal splines).
spotface: A flat surface machined at a right angle to a drilled hole.
spur gear: Gear with straight teeth that are parallel to the shaft axes.
square: A quadrilateral with all sides equal and four 90° angles. See *quadrilateral*.
square foot: Unit of measure containing 144 sq in.
square inch: Unit of measure $1'' \times 1''$ or its equivalent.
stamping: Process of applying pressure from two dies to form a part.
stamping print: Print that describes thin material parts that are formed under pressure to their final shape.
standard series: A screw thread series of coarse (UNC/UNRC), fine (UNF/UNRF), and extra-fine (UNEF/UNREF) graded pitches and eight series with constant pitches. See *thread series*.
straight angle: Angle that contains 180°. See *angle*.
straight line: The shortest distance between two points.
stylus: An electromechanical device used to input information into a computer.
subtraction: The process of taking one number away from another number.
subtrahend: The number which is subtracted.
sum: The result from adding two or more numbers.
supplementary angles: Angles that equal 180°.
surface features: Any part of a surface where change occurs.
symbol: A conventional representation of a quantity or unit.
symmetrical object: An object in which one-half is the mirror image of the other half.

T

T codes: Numerical control codes used to specify the turret stop of the desired tool.
tangent: A straight line touching the circumference at only one point. See *circumference*.
taper: Solid or hollow cylinder in which the diameter increases or decreases uniformly from one end to the other.
taper thread: The thread formed on a cone or frustum of a cone.
tempering: Process of heating metal followed by controlled cooling at a specific rate.
tertiary: The third level of importance.
tetrahedron: A regular solid of four triangles.
thermal expansion: Expansion of a material when subjected to heat.
thermoplastic plastic: Plastic that will soften repeatedly when heat is applied.
thermosetting plastic: Plastic that will soften only once when exposed to heat.
thin section: A sectional view that is too thin to be shown by the ordinary cross-sectioning convention. See *sectional view*.

thousands period: The second period (1,000 through 999,999).

threaded fastener: Any device such as a nut and bolt that joins or fastens parts together with threads.



thread representation: The method of drawing used to show a threaded part.

threads per inch: The reciprocal of the pitch in inches. See *reciprocal* and *pitch*.

through hole: A drilled hole passing completely through the material.

thumbwheel: An electromechanical device used to control the position of a cursor in vertical and horizontal planes. See *cursor*.

tolerance: The amount of variation allowed above or below a dimension.

tooth face: Curved surface of a tooth located above the pitch circle between the pitch circle and addendum circle. See *pitch circle* and *addendum circle*.

tooth flank: Curved surface of a tooth located below the pitch circle between the pitch circle and dedendum circle. See *pitch circle* and *addendum circle*.

top auxiliary view: A primary auxiliary view that has the inclined surface perpendicular to the top plane and is hinged to the top plane. See *primary auxiliary view*.

torque: Product of the applied force (P) times the distance (L) from the center of application.

total indicator reading (TIR): The maximum variation from smallest to largest indicator reading.

toughness: Combination of strength and ductility of a material.

trace point: The point of contact between the cam and cam follower.

trackball: An electromechanical device similar to a thumbwheel in that it is only used to control cursor movement. See *cursor*.

translucent: Allowing light to pass through.

translucent paper: Paper that allows light to pass through.

transverse (back) pitch: The distance from the center of one row of rivets to the center of the adjacent row of rivets.

trapezoid: A quadrilateral with two sides parallel. See *quadrilateral*.

trapezium: A quadrilateral with no sides parallel. See *quadrilateral*.

triangle: A three-sided polygon with three interior angles. All triangles contain 180°. See *polygon*.

trimetric: An axonometric drawing with all axes drawn at different angles. See *axonometric*.

true view: A view in which the line of sight is perpendicular to the surface.

turning: A cutting operation performed with the work rotating and the cutting tool fed into or away from the work.

U

undercut: Recessed area machined at the intersection of two perpendicular planes.

units period: The first period (000 through 999).

V

vellum: A translucent paper made from a rag base. See *translucent paper*.

vertex: The point opposite from the base of a figure.

vertical: Straight, upward position.

vertical line: A line in a straight, upward position.

volume: The three-dimensional size of an object measured in cubic units. See *cubic inch* and *cubic foot*.

W

welding prints: Prints that describe several pieces that are welded together to make a finished part.

whole depth: Total distance of the tooth from the dedendum circle to the addendum circle. See *dedendum* and *addendum circle*.

whole number: Any number that has no fractional or decimal parts.

working depth: Depth a tooth extends into the tooth space when in full mesh with proper clearance.

working drawing: A set of plans that contains the information necessary to complete a job.

worm gears: Gears that consist of a worm and worm gear used for large speed reduction.

X

X, Y, and Z codes: Numerical control codes used to specify movement along one of the primary axes.

Y

Z

⊥ .002 X

Index

ISBN 0-8269-1864-6

90000

9 780826 918642